(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 February 2004 (12.02.2004)

PCT

(10) International Publication Number
WO 2004/013119 A1

(51) International Patent Classification[7]: C07D 317/06, A61K 31/357, A61P 27/00

(21) International Application Number: PCT/US2003/024305

(22) International Filing Date: 4 August 2003 (04.08.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/212,437 5 August 2002 (05.08.2002) US

(71) Applicant: **ALLERGAN, INC.** [US/US]; 2525 Dupont Drive, Irvine, CA 92612 (US).

(72) Inventors: **LING, Kah-Hiing, John**; 82 Lessay, Newport Coast, CA 92657 (US). **YANG, Wu**; 1 Corte Trovata, Irvine, CA 92606 (US). **NI, Jinsong**; 9 Coca, Foothill Ranch, CA 92610 (US). **YUAN, Haiqing**; 28 Del Trevi, Irvine, CA 92606 (US). **TANG-LIU, Diane, D., S.**; 2615 Blackthorn Street, Newport Beach, CA 92660 (US).

(74) Agents: **FISHER, Carlos, A.** et al.; c/o Allergan, Inc., 2525 Dupont Drive, Irvine, CA 92612 (US).

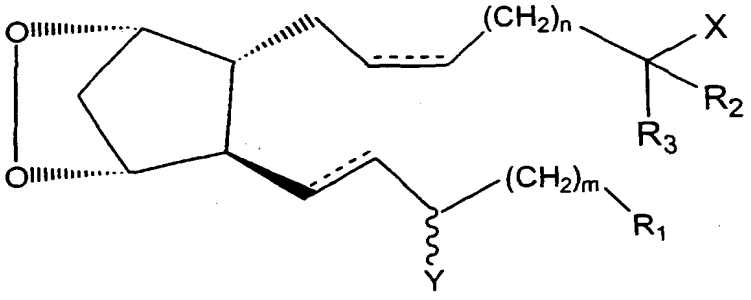
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: THE 9, 11-CYCLOENDOPEROXIDE PRO-DRUGS OF PROSTAGLANDIN ANALOGUES FOR TREATMENT OF OCULAR HYPERTENSION AND GLAUCOMA



(I)

(57) Abstract: 9,11-Cycloendoperoxide derivatives of biologically active prostaglandin analogs, and particularly of the ocular hypotensive drugs Bimatoprost, Latanaprost, Unoprostone, Travoprost and prostaglandin H_2 1-ethanolamide or of structurally closely related analogs, are pro-drugs which hydrolyze under physiological conditions to provide prostaglandin analogues that are capable of providing sustained ocular and other in vivo concentrations of the respective drugs. The compounds of the invention have the formula shown below where the variables have the meaning defined in the specification.

WO 2004/013119 A1

THE 9,11-CYCLOENDOPEROXIDE PRO-DRUGS OF PROSTAGLANDIN ANALOGUES FOR TREATMENT OF OCULAR HYPERTENSION AND GLAUCOMA

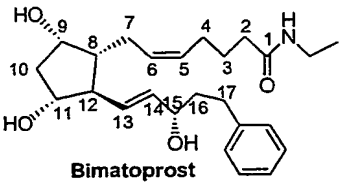
BACKGROUND OF THE INVENTION

Field of the Invention

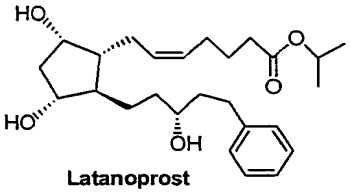
The present invention is in the field of prostaglandin and analog drugs. More particularly the present invention is in the field of prostaglandin analog drugs which are used for treatment of ocular hypertension, glaucoma or have other useful pharmacological properties. Still more particularly, the present invention is directed to pro-drugs of prostaglandin analogs which are used for treatment of ocular hypertension, glaucoma, have beneficial effects on platelet congregation, gastric ulceration, blood pressure regulation and inflammation.

Background Art

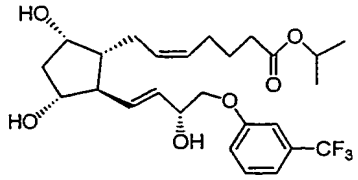
Several prostaglandin analogs are presently known for their ability to reduce intraocular pressure and can be used for treatment of glaucoma and related diseases of the eye. Among these the drugs known by the names Bimatoprost (U. S. Patent No. 5,688,819) Latanoprost (U. S. Patent Nos. 4,599,353, 5,296,504, 5,422,368), Unoprostone (U. S. Patent No. 6,329,426) and Travoprost (U. S. Patent Nos.5,631,287, 5,849,792, 5,889,052, 6,011,062) are mentioned as important ones in current use, and are shown by chemical structure below. The conventional numbering of prostaglandins and like structures is indicated in connection with the formula of Bimatoprost.



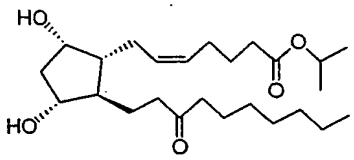
Bimatoprost



Latanoprost



Travoprost



Unoprostone

SUMMARY OF THE INVENTION

In accordance with the present invention 9,11 cycloendoperoxide derivatives of biologically active prostaglandin analogs comprise pro-drugs which hydrolyze under physiological conditions to provide prostaglandin analogues that are capable of providing sustained ocular and other *in vivo* concentrations of biologically active prostaglandin analogues. See *Fredholm et al.*, Prostaglandins 1976, 11, 507-518 and *Stringfellow et al.*, Prostaglandins 1978, 16, 901-910).

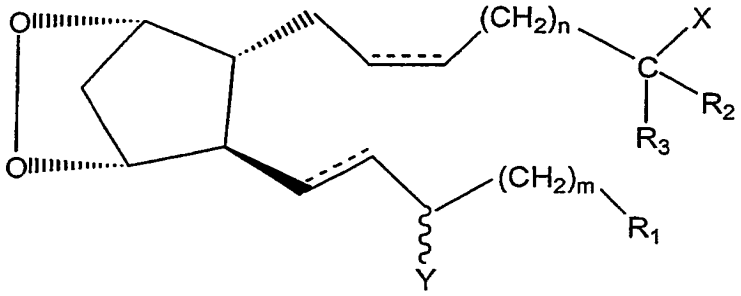
The 9,11-cycloendoperoxide analogs of biologically active prostaglandins are, generally speaking, chemically stable and are converted to the active drugs Bimatoprost, Latanaprost, Unoprostone, Travoprost, and H_2 1-ethanolamide or to structurally closely related analogs, as well as into other biologically active prostglandins, such as prostaglandins D_2, E_2, and F_{2alpha} , thromboxane and prostacyclin analogs, with ocular hypotensive and other biological activity. The thromboxane and prostacyclin analogues effect platelet aggregation and are expected to play a crucial role in preventing gastric ulceration by inhibiting gastric acid secretion, in blood

pressure regulation by control of vascular tone, and in inflammation by inhibiting protease secretion of polymorphonuclear leucocytes.

In addition to being useful as pro-drugs which hydrolyze under physiologic condition to the corresponding drugs, the 9,11-cycloendoperoxides of the invention may *per* se have the biological activity of the corresponding drug into which they hydrolyze, and as such are expected to provide still better sustained physiological concentration of the therapeutic agent which they represent.

The 9,11-cycloendoperoxide pro-drugs of the present invention, in addition to undergoing hydrolysis to provide the corresponding biologically active prostaglandin analogs, also act as substrates to several naturally occurring enzymes which convert the 9,11-cycloendoperoxide pro-drugs into other biologically active analogs wherein the molecular structure is modified. These enzymatic reactions which occur *in vivo* can also be performed *in vitro* by utilizing the corresponding enzymes isolated from human or other mammalian organisms, and are illustrated below in **Reaction Schemes 10** through **20**.

The compounds of the invention are generally disclosed by **Formula 1**,



Formula 1

wherein the dashed lines represent the presence of a bond, or absence of a bond, wavy lines represent either alpha or beta configuration, solid triangles

represent beta configuration and hatched lines represent alpha configuration;

n is an integer having the values of 1 to 6;

m is an integer having the values of 1 to 8;

X is NH_2, $N(R)_2$, NHR, or OR where R is hydrogen, R_4 or a $(CO)R_4$ group;

Y is =O, =S or OH, OR_5 or $--O(CO)R_5$ groups, said OH, OR_5 or $O(CO)R_5$ groups being attached to the adjacent carbon in alpha or beta configuration;

$\mathbf{R_1}$ is H, CH_3, $\mathbf{R_7}$, $\mathbf{OR_7}$ or $\mathbf{SR_7}$ where $\mathbf{R_7}$ is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to 3 $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, or $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;

R_2 and R_3 together represent =O, =S, or independently are hydrogen or alkyl of 1 to 6 carbon atoms;

R_4 represents $(CH_2)_rOH$, $(CH_2)_rOCOR_9$ or $(CH_2)_rOR_9$ where **r** is an integer having the values 1 to 6, or R_4 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_qR_6$ where q is 0-10 and R_6 is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;

R_5 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_qR_6$, or a pharmaceutically acceptable salt of said compound.

DETAILED DESCRIPTION OF THE INVENTION

Definitions:

As used herein the term alkyl refers to and covers any and all groups which are known as normal alkyl, branched-chain alkyl, cycloalkyl and also cycloalkyl-alkyl. The term alkenyl refers to and covers normal alkenyl, branch-chained alkenyl and cycloalkenyl groups having one or more sites of unsaturation. When referring to saturated or unsaturated acyclic hydrocarbons, the term covers normal alkyl, normal alkenyl and normal alkynyl groups as well as branch-chained alkyl, branch-chained alkenyl and branch-chained alkynyl groups, the normal and branch-chained alkenyl and alkynyl groups having one or more sites of unsaturation.

A pharmaceutically acceptable salt may be prepared for any compound in this invention having a functionality capable of forming a salt, for example an acid or amine functionality. A pharmaceutically acceptable salt is any salt which retains the activity of the parent compound and does not impart any deleterious or untoward effect on the subject to which it is administered and in the context in which it is administered.

Pharmaceutically acceptable salts may be derived from organic or inorganic bases. The salt may be a mono or polyvalent ion. Of particular interest are the inorganic ions, sodium, potassium, calcium, and magnesium. Organic salts may be made with amines, particularly ammonium salts such as mono-, di- and trialkyl amines or ethanol amines. Salts may also be formed with caffeine, tromethamine and similar molecules. Where there is a nitrogen sufficiently basic as to be capable of forming acid addition salts, such may be formed with any inorganic or organic acids or alkylating agent such as methyl iodide. Preferred salts are those formed with inorganic acids such as hydrochloric acid, sulfuric acid or phosphoric acid. Any of a number of simple organic acids such as mono-, di- or tri- acid may also be used.

The compounds of the present invention are capable of existing as *trans* and *cis* (E and Z) isomers relative to the five-membered ring shown in the respective formulas, and relative to olefinic double bonds. Unless specific orientation of substituents relative to a double bond or the ring is indicated in the name of the respective compound, and/or by specific showing in the structural formula of the orientation of the substituents relative to the double bond or ring, the invention covers *trans* as well as *cis* isomers relative to each center that gives rise to such isomerism, as well as mixtures of *trans* and *cis* isomers.

The compounds of the present invention also contain one or more chiral centers and therefore may exist in enantiomeric and diastereomeric forms. Again, unless the name of a compound or its formula specifically describes or shows a specific enantiomer or diastereomer, the scope of the present invention is intended to cover all isomers *per se*, as well as mixtures of *cis* and *trans* isomers, mixtures of diastereomers and racemic mixtures of enantiomers (optical isomers) as well.

In the presently preferred compounds of the invention the variable **n** is 3, and the variable **m** is in the range or 1 to 6. The dotted line between carbons 5 and 6 as the numbering is shown on the structure depicting Bimatoprost, preferably represents a bond.

The variable **Y** preferably represents =O or OH, or $O(CO)R_5$, where R_5 is preferably alkyl of 1 to 6 carbons. Even more preferably **Y** is OH attached to the adjacent carbon with a bond of alpha orientation.

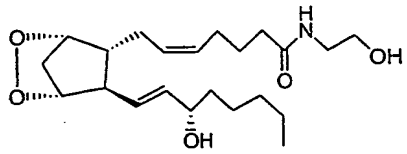
In the presently preferred compounds of the invention $\mathbf{R_1}$ is methyl, phenyl, phenyl substituted in the phenyl group in the manner described in connection with **Formula 1**, or $\mathbf{R_1}$ is O-phenyl, or O-phenyl substituted in the phenyl group in the manner described in connection with **Formula 1**. When $\mathbf{R_1}$ is O-phenyl substituted in the phenyl group then the presently most preferred substituent is trifluoromethyl.

With respect to the group shown as $C(X)(R_2)(R_3)$ in **Formula 1** the R_2 and R_3 groups preferably jointly form an oxo (=O) function, and the variable **X** is preferably OH, OR_4 or NHR_4. R_4 is preferably alkyl of 1 to 6 carbons, or $(CH_2)_rOH$ where most preferably **r** is an integer having the value 2.

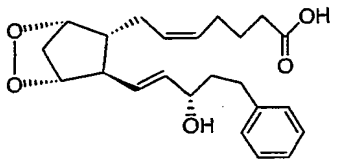
The presently most preferred compounds of the invention are the 9,11-cycloendoperoxide pro-drugs structurally closely related to Bimatoprost, Latanapost, Unoprostone, Travoprost, Bimatoprost acid and of Prostaglandin H_2 1-ethanolamide, the chemical structures of which are provided below. Although these structures show specific examples, they nevertheless generally show the 9,11-cycloendoperoxide moiety which can be introduced into the biologically active prostaglandin analogs by the enzymatic synthetic methods described below in detail. Numbers in parentheses next to the 9,11-cycloendoperoxides illustrated below refer to the specific compound numbers which are utilized in the specific description of examples and corresponding reaction schemes.

The enzymatic methods utilize the enzyme human COX-2 which can be obtained commercially from Cayman Chemical (Ann Arbor, MI). It was cloned in as described by *Hla et al.* in Proc. Natl. Acad. Sci. USA 1992, 89: 7384-7388, incorporated herein by reference. The enzyme was prepared by expression of a DNA clone encoding this enzyme in Baculovirus overexpression system in insect host cells (Sf21 cells).

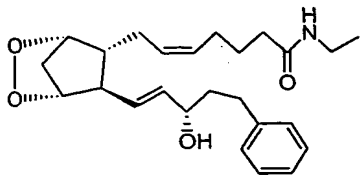
The compounds on which the enzymatic syntheses utilizing the enzyme human COX-2 are performed can be prepared by chemical reactions and/or a combination of chemical and enzymatic reactions which are illustrated below, and by such modifications and adaptation of the chemical and/or enzymatic reactions which are within the skill of the practicing synthetic chemist in light of the present disclosure combined with general knowledge and available scientific and patent literature.



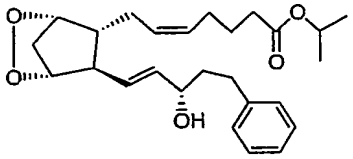
Prostaglandin H_2 1-ethanolamide (17)



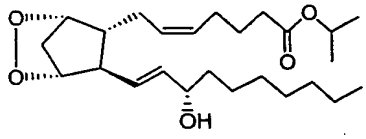
Bimatoprost acid 9,11-cycloendoperoxide (18)



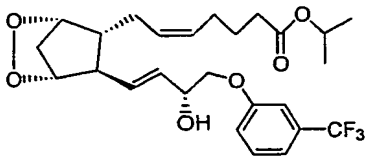
Bimatoprost 9,11-cycloendoperoxide (19)



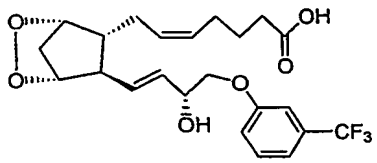
Latanoprost 13,14-dehydro-9,11-cycloendoperoxide (20)



Unoprostone 13,14-dehydro-15-hydroxy-9,11-cycloendoperoxide (21)



Travoprost 9,11-cycloendoperoxide (22)



Travoprost acid 9,11-cycloendoperoxide (23)

BIOLOGICAL ACTIVITY, MODES OF ADMINISTRATION

The compounds of the invention are primarily active as pro-drugs of biologically active prostaglandins or prostaglandin analogs. Because the compounds act primarily as pro-drugs their ultimate biological effect is substantially the same as that of the corresponding drug. However, because the compounds of the invention act as pro-drugs, they tend to release the corresponding drug over a period of time, and therefore are expected to act as a sustained release drug, capable of maintaining a therapeutically effective concentration of the corresponding drug for a longer period of time than the corresponding drug. Still speaking generally, pro-drugs of the present invention are likely to be administered in the same manner as the corresponding drug, and in doses comparable to the administration of the corresponding drug. For specific description of modes of administration and dosages of the known prostaglandin drugs for which the 9,11-cycloendoperoxide compounds of the invention serve as pro-drugs, reference is made to the state of the art and to United States Patent Nos. 5,688,819; 5,296,504; 4,599,353; 5,422,368; 6,329,426, 5,631,287, 5,849,792, 5,889,052 and 6,011,062 the specification of all which is incorporated herein by reference.

The pro-drugs of the present invention may also be administered in combination with the corresponding drug.

An important application of several pro-drugs in accordance with the present invention is treatment of ocular hypertension or glaucoma. For this purpose, similarly to the corresponding drug, such as Bimatoprost, Latanaprost, Unoprostone, Travoprost and prostaglandin H_2 1-ethanolamide, the pro-drug is preferably administered as a topical ophthalmic solution.

Still speaking generally, pharmaceutical compositions may be prepared by combining a therapeutically effective amount of at least one

compound according to the present invention, or a pharmaceutically acceptable salt thereof, as an active ingredient, with conventional pharmaceutical excipients, and in some cases by preparation of unit dosage forms suitable for specific use, such as topical ocular use. The therapeutically efficient amount typically is between about 0.0001 and about 5% (w/v), preferably about 0.001 to about 1.0% (w/v) in liquid formulations.

For ophthalmic application, preferably solutions are prepared using a physiological saline solution as a major vehicle. The pH of such ophthalmic solutions should preferably be maintained between 6.5 and 7.2 with an appropriate buffer system. The formulations may also contain conventional, pharmaceutically acceptable preservatives, stabilizers and surfactants.

Preferred preservatives that may be used in the pharmaceutical compositions of the present invention include, but are not limited to, benzalkonium chloride, chlorobutanol, thimerosal, phenylmercuric acetate and phenylmercuric nitrate. A preferred surfactant is, for example, Tween 80. Likewise, various preferred vehicles may be used in the ophthalmic preparations of the present invention. These vehicles include, but are not limited to, polyvinyl alcohol, povidone, hydroxypropyl methyl cellulose, poloxamers, carboxymethyl cellulose, hydroxyethyl cellulose and purified water.

Tonicity adjustors may be added as needed or convenient. They include, but are not limited to, salts, particularly sodium chloride, potassium chloride, mannitol and glycerin, or any other suitable ophthalmically acceptable tonicity adjustor.

For ophthalmic use various buffers and means for adjusting pH may be used so long as the resulting preparation is ophthalmically acceptable. Accordingly, buffers include acetate buffers, citrate buffers, phosphate

buffers and borate buffers. Acids or bases may be used to adjust the pH of these formulations as needed.

In a similar vein, an ophthalmically acceptable antioxidant for use in the present invention includes, but is not limited to, sodium metabisulfite, sodium thiosulfate, acetylcysteine, butylated hydroxyanisole and butylated hydroxytoluene.

Other excipient components which may be included in the ophthalmic preparations are chelating agents. The preferred chelating agent is edetate disodium, although other chelating agents may also be used in place or in conjunction with it.

The ingredients are usually used in the following amounts:

Ingredient	Amount (% w/v)
active ingredient	about 0.001-5
preservative	0-0.10
vehicle	0-40
tonicity adjustor	1-10
buffer	0.01-10
pH adjustor	q.s. pH 4.5-7.5
antioxidant	as needed
surfactant	as needed
purified water	as needed to make 100%

The actual dose of the active compounds of the present invention depends on the specific compound, and on the condition to be treated; the selection of the appropriate dose is well within the knowledge of the skilled artisan.

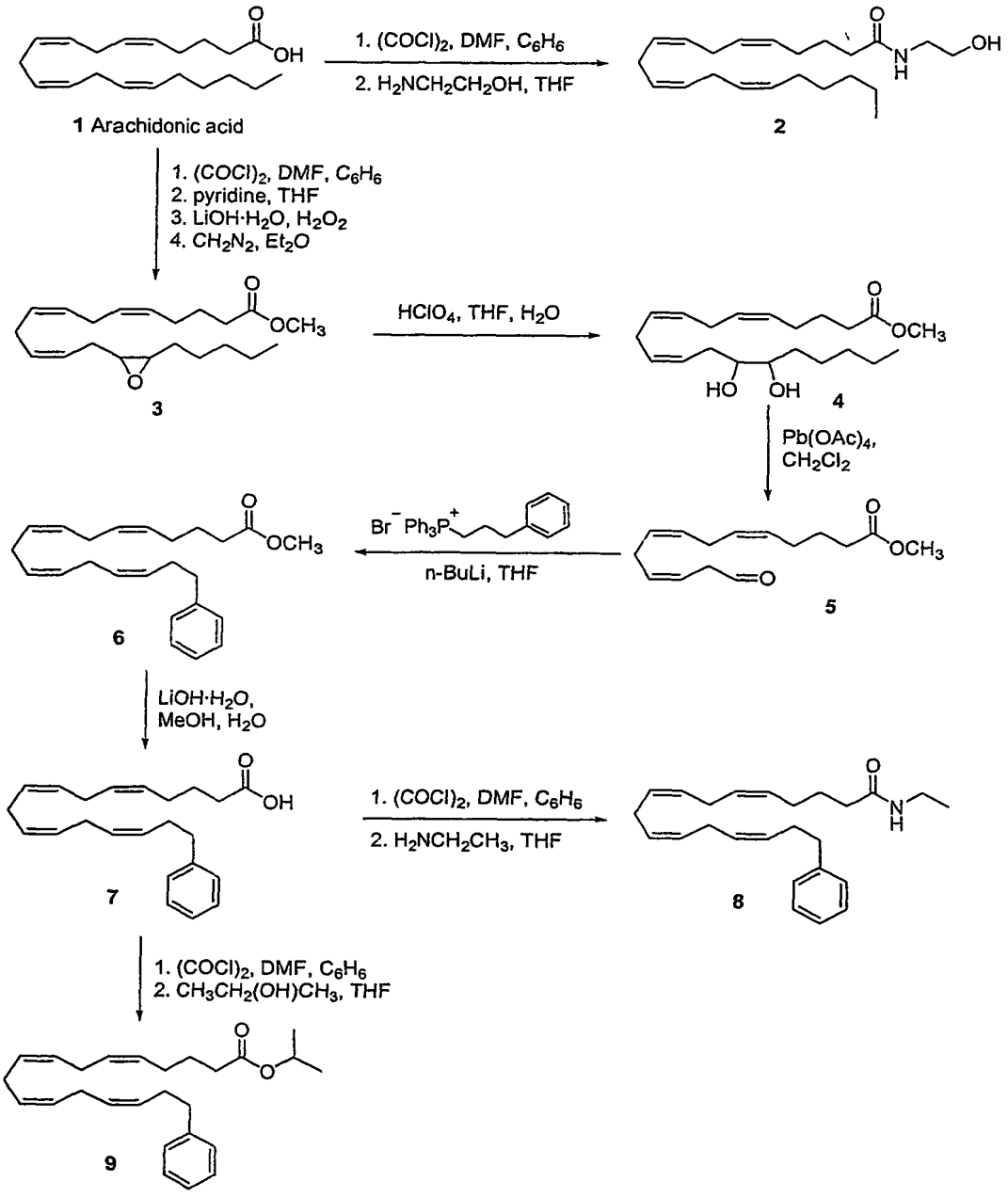
The ophthalmic formulations of the present invention may be conveniently packaged in forms suitable for metered application, such as in containers equipped with a dropper, to facilitate the application to the eye. Containers suitable for drop-wise application are usually made of suitable inert, non-toxic plastic material, and generally contain between about 0.5 and about 15 ml solution.

DESCRIPTION OF SPECIFIC EMBODIMENTS AND EXAMPLES

General Procedure A

Chemical synthesis of arachidonyl ethanolamide (**Compound 2**)

The chemical synthesis of arachidonyl ethanolamide from arachidonic acid (**Compound 1**) is illustrated in **Reaction Scheme 1**. Arachidonyl ethanolamide (**Compound 2**) is synthesized following a literature procedure of *Abadji et al.*, J. Med. Chem. 1994, 37, 1889-1893, incorporated herein by reference. To a 0.1 M solution of arachidonic acid (**Compound 1**, available from Cayman Chemical) in anhydrous benzene at 0 °C is added one equivalent of anhydrous dimethyl formamide and two equivalents of oxalyl chloride. The reaction is stirred at room temperature for 1 h and an equal volume of anhydrous tetrahydrofuran (THF) is added. The mixture is then cooled to 0 °C and a 1 M solution of 10 equivalents 2-amino-ethanol in anhydrous THF is added. The reaction is stirred at room temperature until completion. The reaction mixture is then diluted with chloroform, washed successively with 1 M HCl, 1 M NaOH, brine, dried over Na_2SO_4, and concentrated *in vacuo*. The crude product is purified by chromatography on silica gel. Arachidonyl ethanolamide (**Compound 2**) is enzymatically converted into the corresponding 9,11-cycloendoperoxide derivative as shown in **Reaction Scheme 3** and is described below.



REACTION SCHEME 1

Chemical synthesis of Compound 3

The chemical synthesis of **Compound 3** from arachidonic acid (**Compound 1**) is also illustrated in **Reaction Scheme 1**. **Compound 3** is synthesized by modification of procedures reported by *Ryan et al.* J. Med. Chem. 1997, 40, 3617-3625, based on previous work by *Corey et al.* Tetrahedron Lett. 1983, 24, 37-40 and *Manna et al.* Tetrahedron Lett. 1983, 24, 33-36. The *Ryan et al.*, *Corey et al.*, and *Manna et al.* publications are hereby expressly incorporated by reference. To a 0.4 M solution of arachidonic acid (**Compound 1**) in anhydrous benzene at 0 °C are added two equivalents of oxalyl chloride. The mixture is stirred for overnight while allowed to warm to room temperature. The solvent and excess oxalyl chloride is removed *in vacuo*. The resulting crude acid chloride is dissolved in anhydrous THF to make a ~ 2 M solution. Half an equivalent of pyridine is added to the above solution and the mixture is stirred for 10 min at 0 °C. 0.7 M solution of $LiOH \cdot H_2O$ in 50% H_2O_2 containing one equivalent of $LiOH \cdot H_2O$ is added and the mixture is stirred for 20 min. The reaction is quenched with pH 7 buffer and brine and extracted with CH_2Cl_2 (×3). The combined organic layer is washed with brine and dried over Na_2SO_4. During this time the epoxy acid is formed and its formation can be monitored by TLC analysis. Upon completion, the drying agent is removed by filtration and the solvent is removed *in vacuo*. The residue is dissolved in anhydrous Et_2O and treated with excess diazomethane. After stirring for 15 min, excess diazomethane is evaporated in a fume hood at room temperature and the solvent is removed *in vacuo*. The crude product is purified by chromatography on silica gel.

Chemical synthesis of Compound 4

The chemical synthesis of **Compound 4** from **Compound 3** is also illustrated in **Reaction Scheme 1**. **Compound 4** is synthesized following

procedures reported by *Ryan et al.* J. Med. Chem. 1997, 40, 3617-3625. A 0.05 M solution of **Compound 3** in THF-H_2O (2:1) is treated with five equivalents of 1.2 M $HClO_4$ at room temperature for overnight. The reaction mixture is then quenched with pH 7 buffer and extracted with EtOAc (×3). The combined organic layer is washed with brine, dried over Na_2SO_4, and concentrated *in vacuo*. The residue is purified by chromatography on silica gel.

Chemical synthesis of Compound 5

The chemical synthesis of **Compound 5** from **Compound 4** is also illustrated in **Reaction Scheme 1**. **Compound 5** is synthesized following procedures reported by *Ryan et al. J.* Med. Chem. 1997, 40, 3617-3625. A 0.2 M solution of **Compound 4** in CH_2Cl_2 at –20 °C is treated with one equivalent of lead (IV) tetraacetate (0.2 M solution in CH_2Cl_2) for 0.5 h. The reaction mixture is filtered through a pad of celite-silica gel and washed with hexane. The solvent is removed *in vacuo* to afford **Compound 5** which is unstable and is used immediately in the next reaction.

General Procedure B

Chemical synthesis of Compound 6

The chemical synthesis of **Compound 6** from **Compound 5** is also illustrated in **Reaction Scheme 1**. **Compound 6** is synthesized by Wittig olefination of **Compound 5** with the ylide triphenyl-(3-phenyl-propylidene)- δ^5-phosphane. The ylide is generated by adding one equivalent of *n*-butyllithium to a 0.3M solution of triphenyl-(3-phenyl-propyl)phosphonium bromide (available from Lancaster) in THF at –78 °C. After stirring for 30 min, 0.7 equivalent of **Compound 5** in THF is added and the reaction is warmed to room temperature and stirred for 1 h. After completion, the reaction is diluted with hexane, washed successively with

pH 7 buffer, brine, dried over Na_2SO_4, and concentrated *in vacuo*. The crude product is purified by chromatography on silica gel.

General Procedure C

Chemical synthesis of Compound 7

The chemical synthesis of **Compound 7** from **Compound 6** is also illustrated in **Reaction Scheme 1**. A mixture of **Compound 6** and 7 equivalents of lithium hydroxide monohydrate in methanol-water (3:1) is heated to 50 °C until the reaction is complete by TLC analysis. The reaction mixture is cooled to room temperature, quenched with aqueous NH_4Cl and extracted with ethyl acetate (×3). The combined organic layer is washed with H_2O, brine, dried over Na_2SO_4, and concentrated *in vacuo*. The crude product is purified by chromatography on silica gel. **Compound 7** is enzymatically converted into the corresponding 9,11-cycloendoperoxide derivative as shown in **Reaction Scheme 4** and is described below.

Chemical synthesis of Compound 8

Compound 8 is synthesized following General Procedure A, using ethyl amine instead of 2-amino-ethanol, as illustrated in **Reaction Scheme 1**. **Compound 8** is enzymatically converted into the corresponding 9,11-cycloendoperoxide derivative as shown in **Reaction Scheme 5** and is described below.

Chemical synthesis of Compound 9

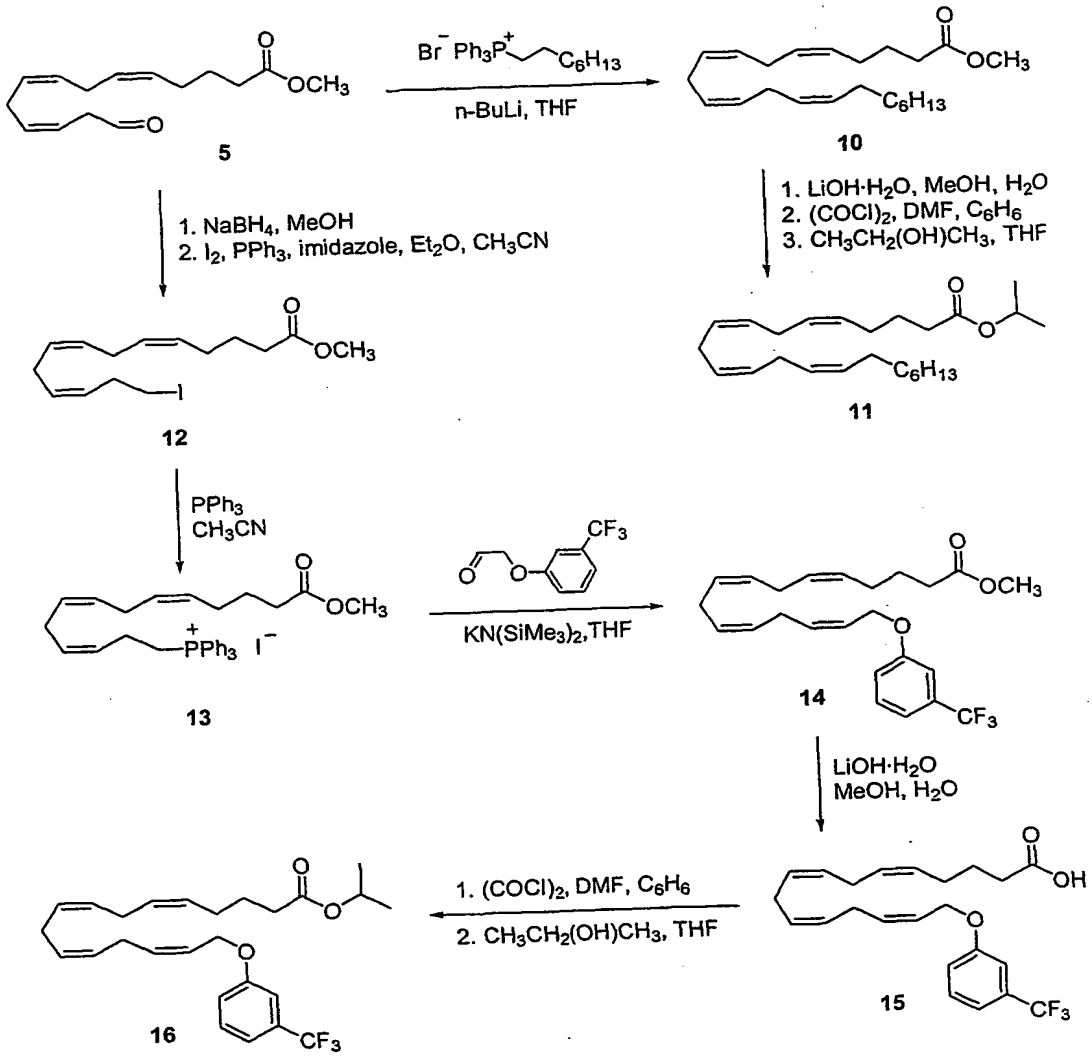
Compound 9 is synthesized following General Procedure A, using isopropyl alcohol instead of 2-amino-ethanol, as illustrated in **Reaction Scheme 1**. **Compound 9** is enzymatically converted into the corresponding 9,11-cycloendoperoxide derivative as shown in **Reaction Scheme 6** and is described below.

Chemical synthesis of Compound 10

Compound 10 is synthesized by Wittig olefination following General Procedure B, using **Compound 5** and (*n*-octyl)triphenylphosphonium bromide (available from Lancaster) instead of triphenyl-(3-phenyl-propyl)phosphonium bromide, as illustrated in **Reaction Scheme 2**.

Chemical synthesis of Compound 11

Compound 11 is synthesized in a three step sequence following General Procedure C and General Procedure A, using isopropyl alcohol instead of 2-amino-ethanol as illustrated in **Reaction Scheme 2**. **Compound 11** is enzymatically converted into the corresponding 9,11-cycloendoperoxide derivative as shown in **Reaction Scheme 7** and is described below.



REACTION SCHEME 2

1

Chemical synthesis of Compound 12

Compound 12 is synthesized from **Compound 5** following procedures reported by Seltzman (*Seltzman et al.* J. Med. Chem. 1997, 40, 3626-3634) and Razdan (*Dasse et al.* Tetrahedron 2000, 56, 9195-9202), as illustrated in **Reaction Scheme 2**. To a 0.25 M solution of **Compound 5** in methanol at 0 °C is added 2 equivalents of $NaBH_4$. The reaction is warmed to room temperature and is monitored by TLC analysis. After completion, the reaction is quenched with aqueous NH_4Cl and is extracted with EtOAc (×3). The combined organic layer is washed with H_2O, brine, dried over Na_2SO_4, and concentrated *in vacuo*. The crude product alcohol is purified by chromatography on silica gel. This intermediate alcohol is then converted to **Compound 12** following Razdan's procedures (Dasse *et al.* Tetrahedron 2000, 56, 9195-9202.) 1.1 equivalent of I_2 is added portion-wise to a solution of 1.1 equivalent of triphenylphosphine and 1.1 equivalent of imidazole in Et_2O-CH_3CN (3:1) at 0 °C. The mixture is stirred at room temperature for 20 min, cooled to 0 °C. To this mixture is added the intermediate alcohol and the reaction is stirred at room temperature for 1 h. The reaction is then diluted with pentane-Et_2O (4:1), filtered through a pad of silica gel to afford **Compound 12**.

Chemical synthesis of Compound 13

Compound 13 is synthesized from **Compound 12** following procedures reported by Razdan (*Ryan et al.* J. Med. Chem. 1997, 40, 3617-3625; and *Dasse et al.* Tetrahedron 2000, 56, 9195-9202), as illustrated in **Reaction Scheme 2**. A 0.2 M solution of Compound 12 and 1.1 equivalent of triphenylphosphine in CH_3CN is heated to reflux until completion of the reaction. The solvent is removed *in vacuo* and the residue is purified by washing with hexane-benzene (1:1). The product is dried in a vacum oven and used directly in the next Wittig reaction.

Chemical synthesis of Compound 14

The chemical synthesis of **Compound 14** is illustrated in **Reaction Scheme 2**. To a 0.3 M solution of **Compound 13** in THF at –78 °C is added 1 equivalent of potassium bis(trimethylsilyl)amide (available from Aldrich). The mixture is stirred at –78 °C for 30 min. A solution of 1.5 equivalent of (3-trifluoromethyl-phenoxy)-acetaldehyde (prepared by reducing 3-(trifluoromethyl)phenoxyacetonitrile (available from Lancaster) with diisobutylaluminum hydride) in THF is added dropwise to the above mixture and the reaction is gradually warmed to room temperature. Upon completion, the reaction is diluted with heaxans, washed with pH 7 buffer, brine, dried over Na_2SO_4, and concentrated *in vacuo*. The crude product is purified by chromatography on silica gel.

Chemical synthesis of Compound 15

Compound 15 is synthesized from **Compound 14** following General Procedure C as illustrated in **Reaction Scheme 2. Compound 15** is enzymatically converted into the corresponding 9,11-cycloendoperoxide derivative as shown in **Reaction Scheme 8** and is described below.

Chemical synthesis of Compound 16

Compound 16 is synthesized from **Compound 14** following General Procedure A, using isopropyl alcohol instead of 2-aminoethanol, as illustrated in **Reaction Scheme 2. Compound 16** is enzymatically converted into the corresponding 9,11-cycloendoperoxide derivative as shown in **Reaction Scheme 9** and is described below.

General Procedure D

Enzymatic synthesis of 9,11-cycloendoperoxide of Prostaglandin H_2 1-ethanolamide (**Compound 17**)

The human COX-2 catalyzed biosynthesis of Prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (**Compound 17**) from its arachidonyl ethanolamide (**Compound 2**) is illustrated in **Reaction Scheme 3**. The enzyme human COX-2 was obtained commercially from Cayman Chemical (Ann Arbor, MI). It was cloned in 1992 (see the publication by *Hla et al. supra*). The enzyme was prepared by expression of a DNA clone encoding this enzyme in Baculovirus overexpression system in insect host cells (Sf21 cells). Ten μM [^{3}H]arachidonyl ethanolamide (**Compound 2**) with a specific activity of 860 μCi/7 mg in 20 μl of ethanolic solution was diluted with 960 μl of the COX-2 (hCOX-2) reaction buffer (100 mM Tris-HCl, pH 8.0, containing 2 mM phenol, 5 μM hematin and 1 mM EDTA). One hundred units of hCOX-2 enzyme preparation in 20 μl of hCOX-2 buffer were added to start enzyme reaction. The total incubation volume was 1 ml. The enzyme reaction was stopped by adding 1 ml dry ice-cooled stop solution (ether: methanol: 1 M acetic acid, 30:4:1, v/v) immediately after incubation at 37°C for 2 minutes. The synthesized products were extracted two times with 3 ml of ethyl acetate each. The organic phase was collected and dried at room temperature under nitrogen. The resulting residue was reconstituted in 150 μl of acetonitrile / water (1:1, v/v) for HPLC-Radiometric analysis and LC/MS/MS analysis. The LC/MS/MS analysis of the synthesized 9,11-cycloendoperoxide of prostaglandin H_2 1-ethanolamide eluting at 31.6 minutes indicated that its molecular weight was 395 daltons. The yield of the synthesis as determined by HPLC-Radiometric analysis was 30%.

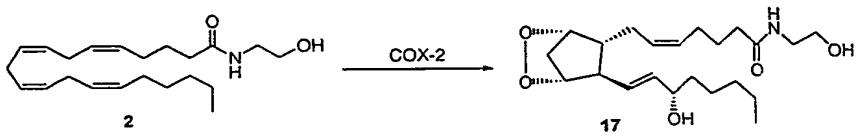
Enzymatic synthesis of Bimatoprost acid 9,11-cycloendoperoxide (**Compound 18**)

Bimatoprost acid 9,11-cycloendoperoxide (**Compound 18**) is synthesized following General Procedure D using **Compound 7**, instead of

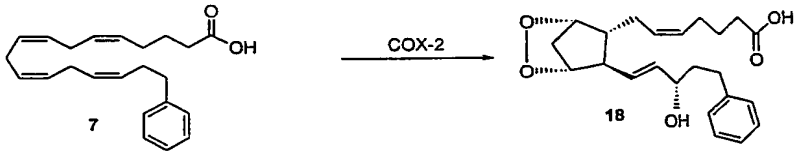
arachidonyl ethanolamide (**Compound 2**), as illustrated in **Reaction Scheme 4**.

Enzymatic synthesis of Bimatoprost 9,11-cycloendoperoxide (**Compound 19**)

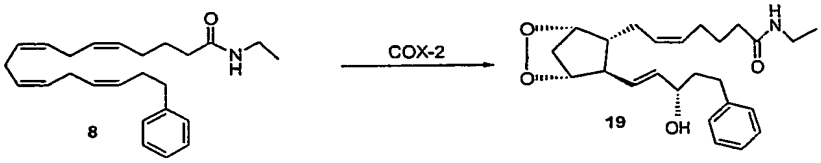
Bimatoprost 9,11-cycloendoperoxide (**Compound 19**) is synthesized following General Procedure D using **Compound 8** instead of arachidonyl ethanolamide (**Compound 2**) as illustrated in **Reaction Scheme 5**.



REACTION SCHEME 3



REACTION SCHEME 4



REACTION SCHEME 5

Enzymatic synthesis of Latanoprost 13,14-dehydro-9,11-cycloendoperoxide (**Compound 20**)

Latanoprost 13,14-dehydro-9,11-cycloendoperoxide (**Compound 20**) is synthesized following General Procedure D using **Compound 9** instead

of arachidonyl ethanolamide (**Compound 2**), as illustrated in **Reaction Scheme 6**.

Enzymatic synthesis of Unoprostone 15-hydroxy-9,11-cycloendoperoxide (**Compound 21**)

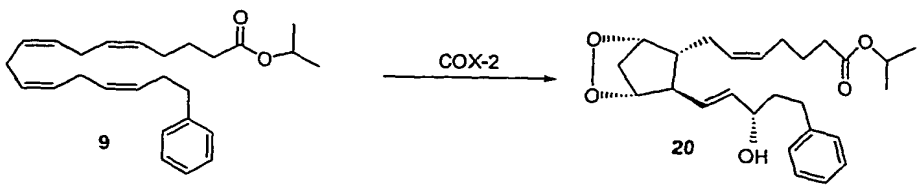
Unoprostone 15-hydroxy-9,11-cycloendoperoxide (**Compound 21**) is synthesized following General Procedure D using **Compound 11** instead of arachidonyl ethanolamide (**Compound 2**) as illustrated in **Reaction Scheme 7**.

Enzymatic synthesis of Travoprost 9,11-cycloendoperoxide (**Compound 22**)

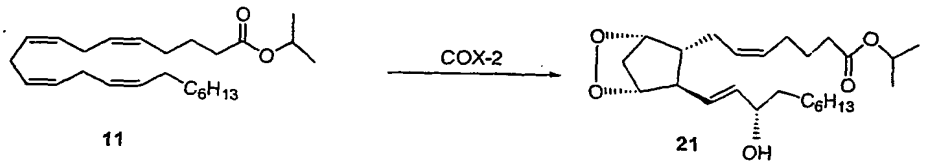
Travoprost 9,11-cycloendoperoxide (**Compound 22**) is synthesized following General Procedure D using **Compound 15** instead of arachidonyl ethanolamide (**Compound 2**) as illustrated in **Reaction Scheme 8**.

Enzymatic synthesis of Travoprost acid 9,11-cycloendoperoxide (**Compound 23**)

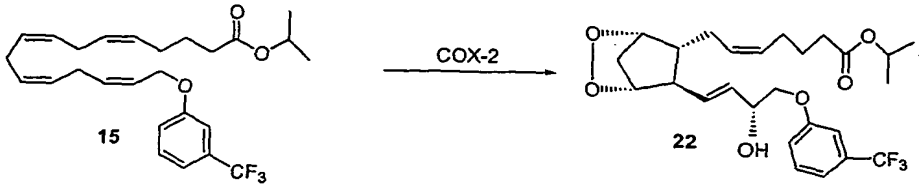
Travoprost acid 9,11-cycloendoperoxide (**Compound 23**) is synthesized following General Procedure D using **Compound 16** instead of arachidonyl ethanolamide (**Compound 2**) as illustrated in **Reaction Scheme 9**.



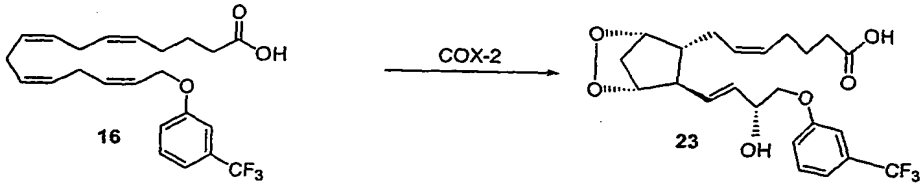
REACTION SCHEME 6



REACTION SCHEME 7

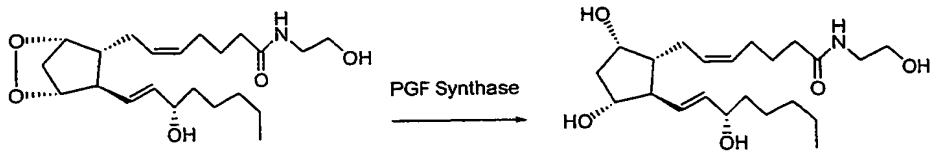


REACTION SCHEME 8



REACTION SCHEME 9

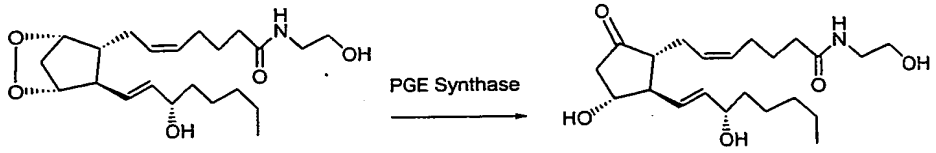
As noted above in the Summary section of the present application for patent, the 9,11-cyclopendoperoxide pro-drugs of the present invention, in addition to undergoing hydrolysis to provide the corresponding biologically active prostaglandin analogs, also act as substrates to several naturally occurring enzymes which convert the 9,11-cyclopendoperoxide pro-drugs into other biologically active analogs. Several of these enzymatic reactions which are expected to occur *in vivo* can be performed *in vitro* in accordance with the present invention resulting in the enzymatic synthesis from the 9,11-cycloendoperoxides of the invention of several biologically active prostaglandin analogs. These enzymatic reactions are illustrated below in **Reaction Schemes 10** through **20**.



Prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (17)

Prostaglandin $F_{2\alpha}$ 1-ethanolamide (24)

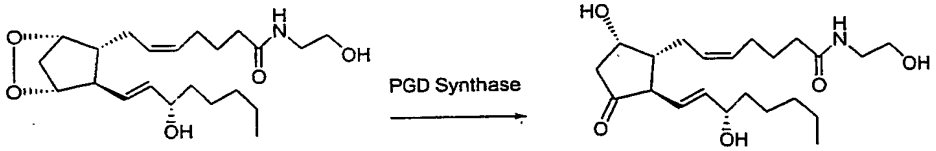
REACTION SCHEME 10



Prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (17)

Prostaglandin E_2 1-ethanolamide (25)

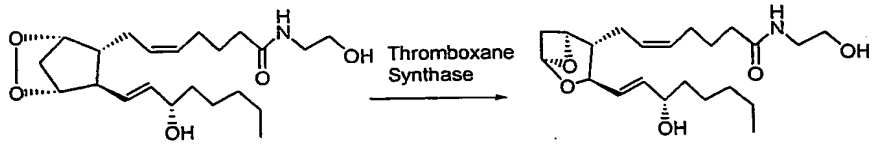
REACTION SCHEME 11



Prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (17)

Prostaglandin D_2 1-ethanolamide (26)

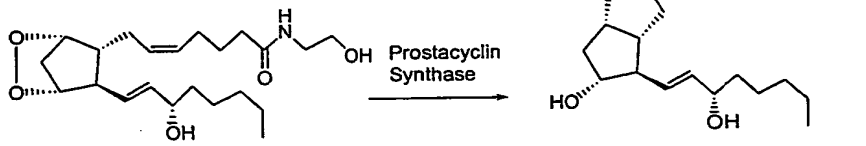
REACTION SCHEME 12



Prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (17)

Thromboxane A_2 1-ethanolamide (27)

REACTION SCHEME 13



Prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (17)

Prostacyclin 1-ethanolamide (28)

REACTION SCHEME 14

General Procedure E

Enzymatic synthesis of Prostaglandin $F_{2\alpha}$ 1-ethanolamide (**Compound 24**)

The human recombinant PGF synthase catalyzed biosynthesis of Prostaglandin $F_{2\alpha}$ 1-ethanolamide from prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (**Compound 17**) is illustrated above in **Reaction Scheme 10**. 4.5 μM [^{3}H]Prostaglandin H_2 1-ethanolamide with a specific activity of 860 mCi/7 mg reconstituted in 0.6 ml of PGF synthase reaction buffer was incubated with 100 μl of the human recombinant PGF synthase solution (1.5 mg/ml) at 37°C for 10 minutes. The cDNA clone of human PGF synthase was isolated from human lung and its enzyme was prepared by expression of cDNA clones in E. coli as described in the publication by *Suzuki-Yamamoto et al.*, FEBS lett, 1999,462: 335-340, incorporated herein by reference. The plasmid was transformed into DH5 α E.coli strain and grown in LB/ampicillin medium. The expressed enzyme in E. coli was partially purified to yield a protein concentration of 15 mg per ml. The pUC8 vectors carrying no PGF synthase DNA insert were also transformed and prepared with protein concentration of 5 mg per ml as a negative control. The enzyme reaction was stopped by adding 1 ml dry ice-cooled stop solution (ether: methanol: 1 M acetic acid, 30:4:1, v/v) immediately after incubation at 37°C for 10 minutes. The synthesized products were extracted with 3 ml of ethyl acetate. The organic phase was collected and dried at room temperature under nitrogen. The resulting residue was reconstituted in 150 μl of acetonitrile / water (1:1, v/v) for HPLC-Radiometric analysis and LC/MS/MS analysis. The prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide was completely converted to prostaglandin $F_{2\alpha}$ 1-ethanolamide in 10 minutes. The product ion spectrum of m/z 398.4 of the biosynthetic product was identical to the standard prostaglandin $F_{2\alpha}$ 1-ethanolamide. They both had the major characteristic fragment ion at m/z 62, which represents protonated 2-amino ethanol

group. There was no conversion by the enzyme preparation from same DH5 $_{\alpha}$ cells carrying pUC8 vector without PGF synthase DNA insert. The yield of the synthesis, as determined by HPLC-Radiometric analysis, was 94%.

General Procedure F

Enzymatic synthesis of Prostaglandin E_2 1-ethanolamide (**Compound 25**)

Prostaglandin E_2 1-ethanolamide is synthesized from prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (**Compound 17**) following General Procedure E using the human recombinant PGE synthase obtained in accordance with the publication of *Jakobsson et al.* Proc. Natl. Acad. Sci. USA, 1999, 96: 7220-7225, incorporated herein by reference, instead of the human recombinant PGF synthase, as illustrated in **Reaction Scheme 11.**

General Procedure G

Enzymatic synthesis of Prostaglandin D_2 1-ethanolamide (**Compound 26**)

Prostaglandin D_2 1-ethanolamide is synthesized from its prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (**Compound 17**) following General Procedure E using the human recombinant PGD synthase obtained in accordance with the publication of *Nagata et al.* Proc. Natl. Acad. Sci. USA, 1991, 88: 4020-4024, incorporated herein by reference, instead of the human recombinant PGF synthase, as illustrated in **Reaction Scheme 12.**

General Procedure H

Enzymatic synthesis of Thromboxane A_2 1-ethanolamide (**Compound 27**)

Thromboxane A_2 1-ethanolamide is synthesized from prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (**Compound 17**) following General Procedure E using the human recombinant thromboxane synthase obtained in accordance with the publication of *Miyata et al.*, Eur. J. Biochem, 1994, 224: 273-279, incorporated herein by reference, instead of the human recombinant PGF synthase, as illustrated in **Reaction Scheme 13**.

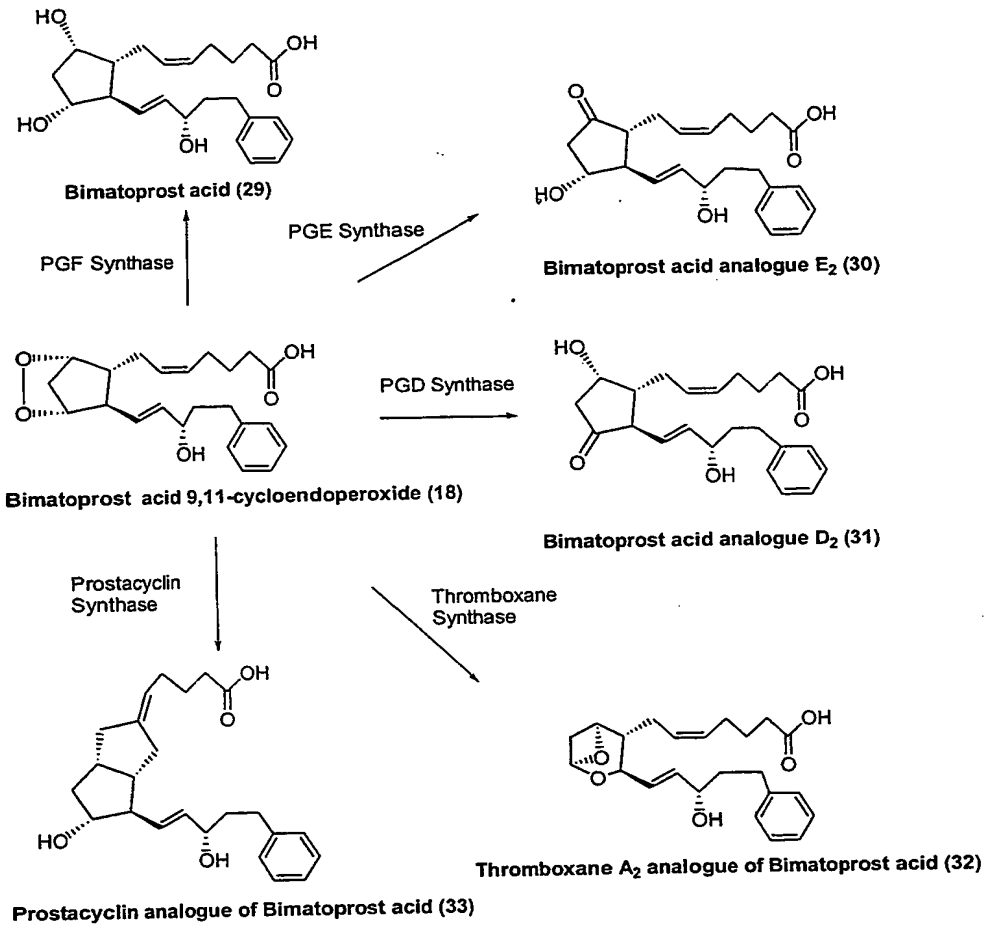
General Procedure I

Enzymatic synthesis of Prostacyclin 1-ethanolamide (**Compound 28**)

Prostacyclin 1-ethanolamide is synthesized from prostaglandin H_2 1-ethanolamide 9,11-cycloendoperoxide (**Compound 17**) following General Procedure E using the human recombinant prostacyclin synthase obtained in accordance with the publication of *Miyata et al.*, Biochem. Biophys. Res. Commun. 1994, 200: 1728-1734, instead of the human recombinant PGF synthase, as illustrated in **Reaction Scheme 14**.

Enzymatic synthesis of Bimatoprost acid (**Compound 29**), its prostaglandin analogues E_2 and D_2 (**Compounds 30-31**), thromboxane analogue A_2 (**Compound 32**) and prostacyclin analogue (**Compound 33**)

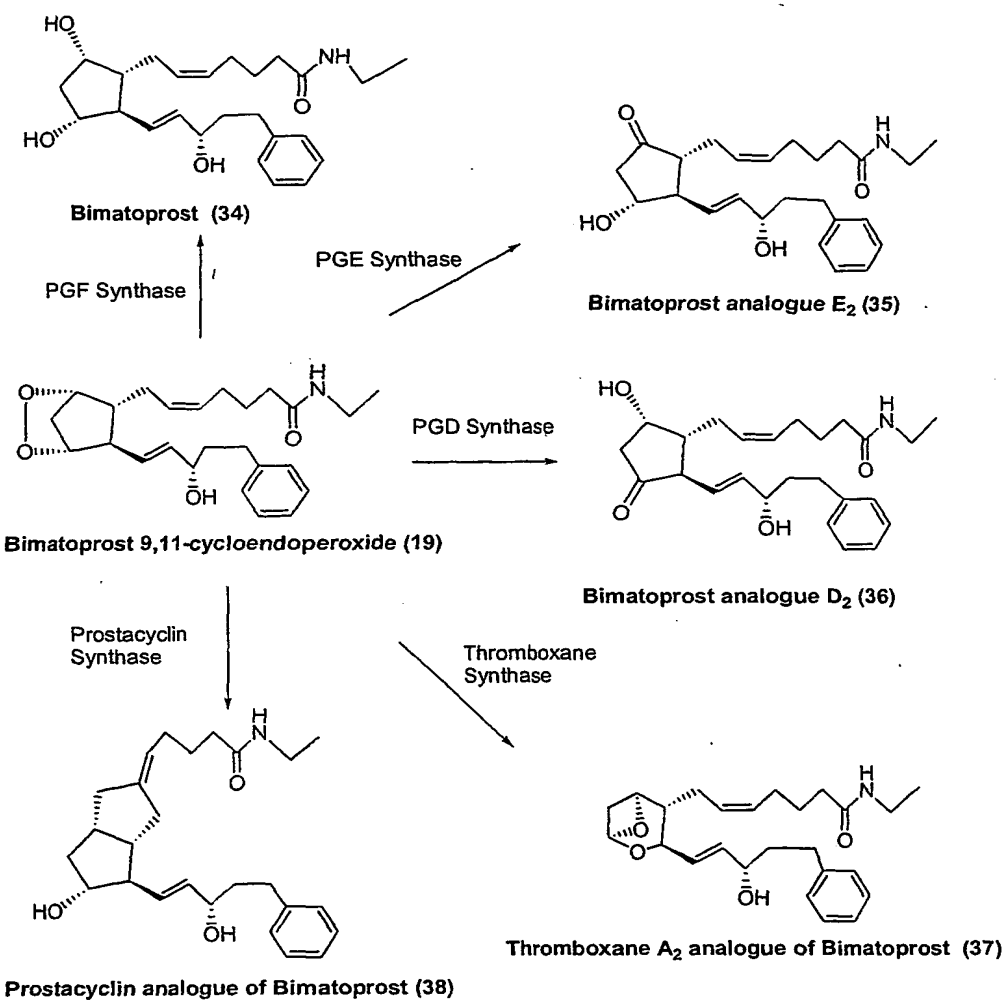
Compounds 29-33 are synthesized starting with Bimatoprost acid 9,11-cycloendoperoxide (**Compound 18**), instead of prostaglandin H_2 1-ethanolamide (**Compound 17**), following General Procedures E, F, G, H and I, respectively, as illustrated in **Reaction Scheme 15** below.



REACTION SCHEME 15

Enzymatic synthesis of Bimatoprost (**Compound 34**), its prostaglandin analogues E_2 and D_2 (**Compounds 35-36**), thromboxane analogue A_2 (**Compound 37**) and prostacyclin analogue (**Compound 38**)

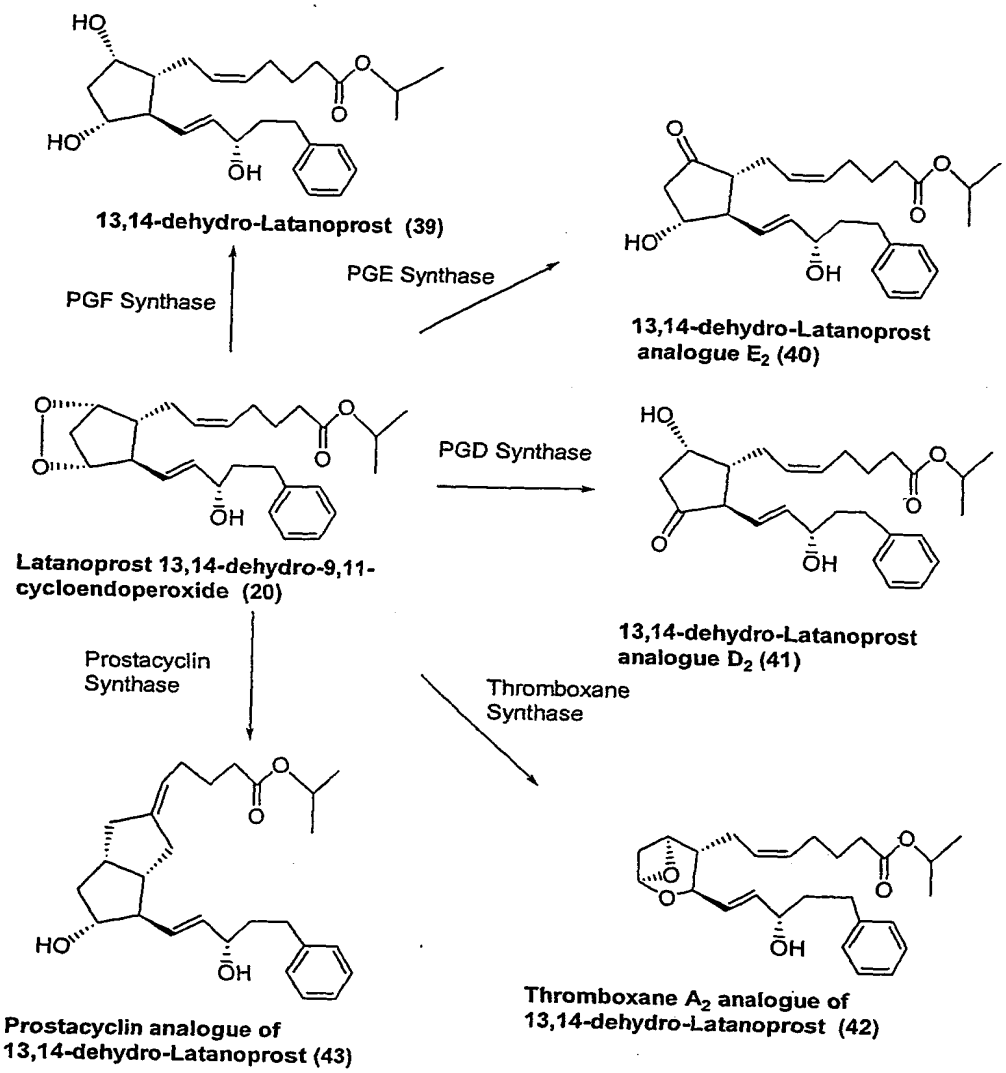
Compounds 34-38 are synthesized from Bimatoprost 9,11-cycloendoperoxide (**Compound 19**), instead of prostaglandin H_2 1-ethanolamide (**Compound 17**), following General Procedures E, F, G, H and I, respectively, as illustrated in **Reaction Scheme 16** below.



REACTION SCHEME 16

Enzymatic synthesis of 13,14-dehydro-Latanoprost (**Compound 39**), its prostaglandin analogues E_2 and D_2 (**Compounds 40-41**), thromboxane analogue A_2 (**Compound 42**) and prostacyclin analogue (**Compounds 43**)

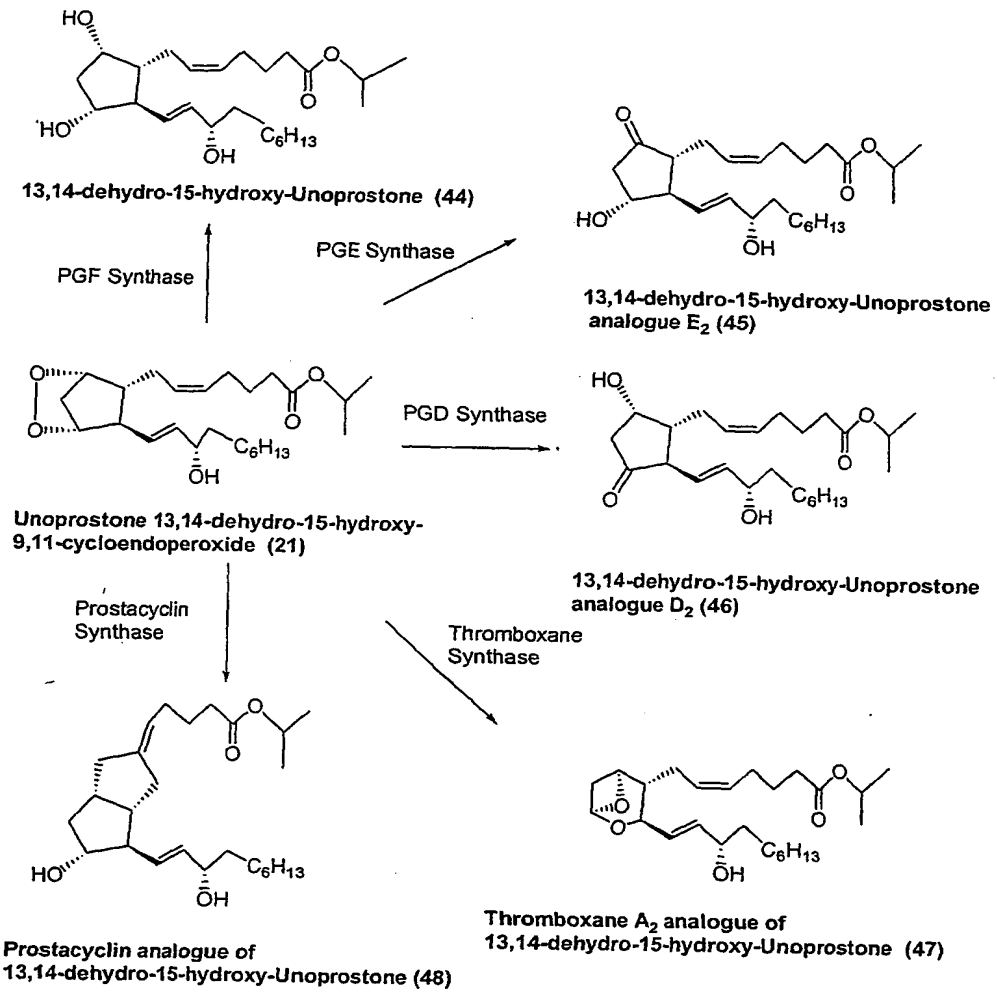
Compounds 39-43 are synthesized from Latanoprost 13,14-dehydro-9,11-cycloendoperoxide (**Compound 20**), instead of prostaglandin H_2 1-ethanolamide, (**Compound 17**) following General Procedures E, F, G, H and I, respectively, as illustrated in **Reaction Scheme 17** below.



REACTION SCHEME 17

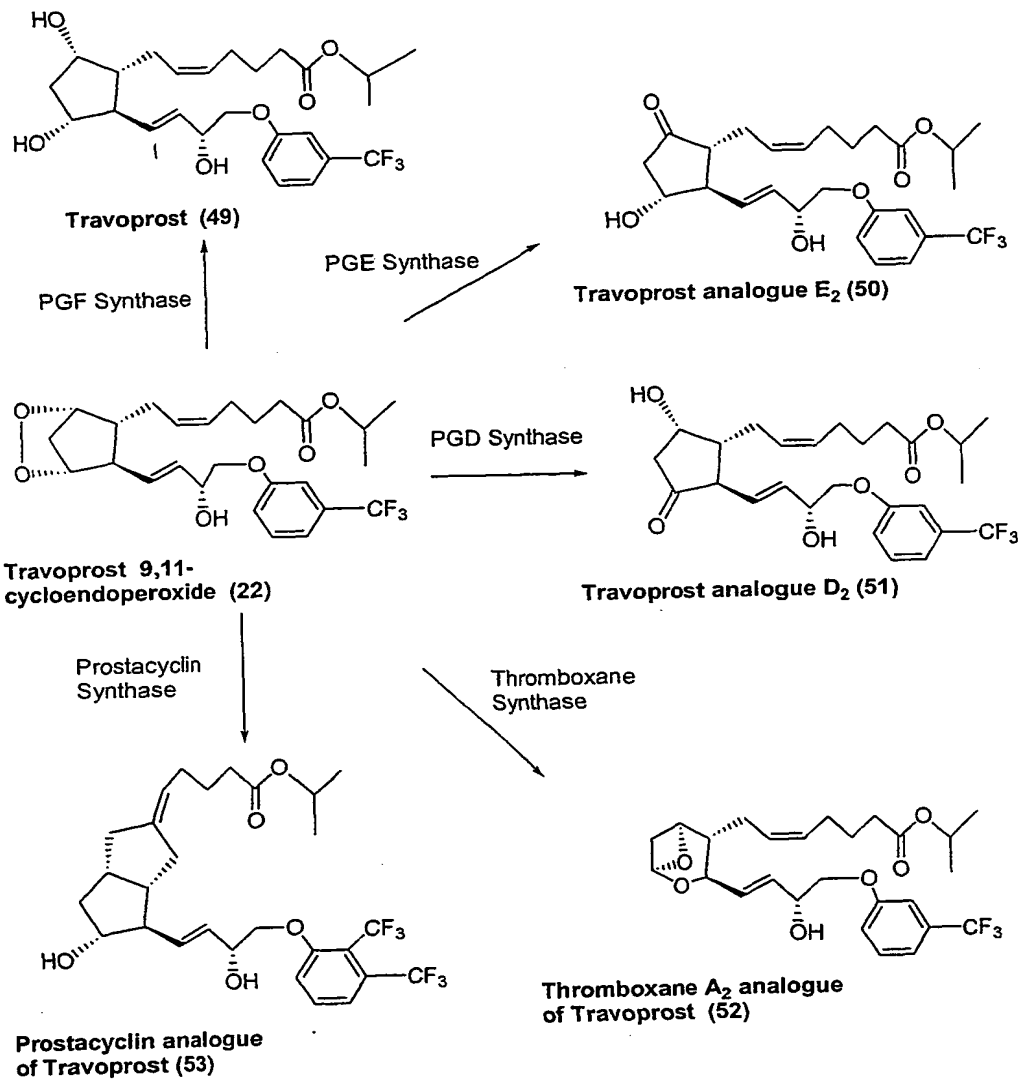
Enzymatic synthesis of 13,14-dehydro-15-hydro-Unoprostone (**Compound 44**), its prostaglandin analogues E_2 and D_2 (**Compounds 45-46**), thromboxane analogue A_2 (**Compound 47**) and prostacyclin analogue (**Compound 48**)

Compounds 44-48 are synthesized from Unoprostone 13,14-dehydro-15-hydroxy-9,11-cycloendoperoxide (**Compound 21**), instead of prostaglandin H_2 1-ethanolamide (**Compound 17**), following General Procedures E, F, G, H and I, respectively, as illustrated in **Reaction Scheme 18** below.



REACTION SCHEME 18

Enzymatic synthesis of Travoprost (**Compound 49**), its prostaglandin analogues E_2 and D_2 (**Compounds 50-51**), thromboxane analogue A_2 (**Compound 52**) and prostacyclin analogue (**Compound 53**) **Compounds 49-53** are synthesized from Travoprost 9,11-cycloendoperoxide (**Compound 22**), instead of prostaglandin H_2 1-ethanolamide (**Compound 17**), following General Procedures E, F, G, H and I, respectively, as illustrated in **Reaction Scheme 19** below.

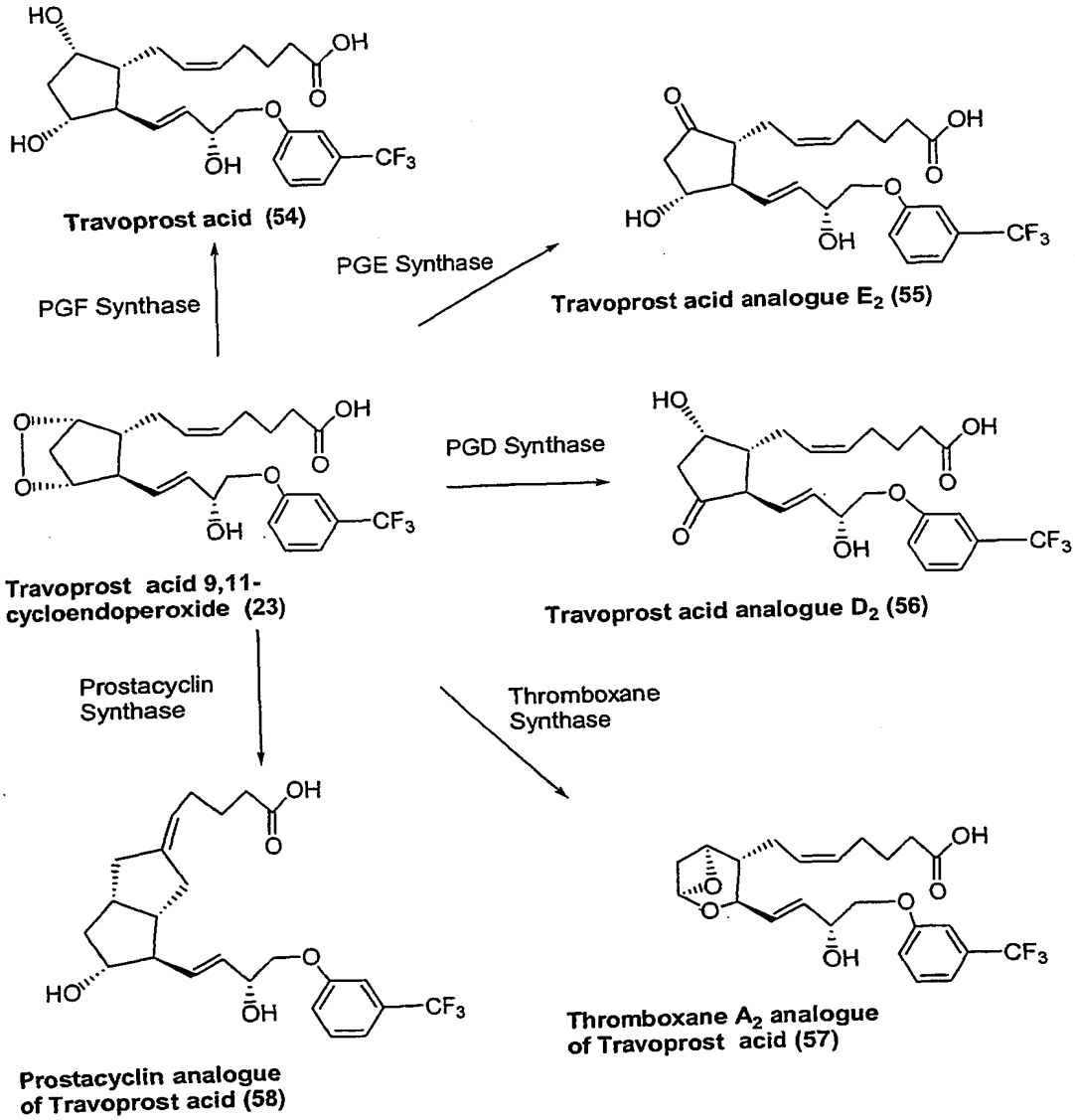


REACTION SCHEME 19

1

Enzymatic synthesis of Travoprost acid (**Compound 54**), its prostaglandin analogues E_2 and D_2 (**Compounds 55-56**), thromboxane analogue A_2 (**Compound 57**) and prostacyclin analogue (**Compounds 58**)

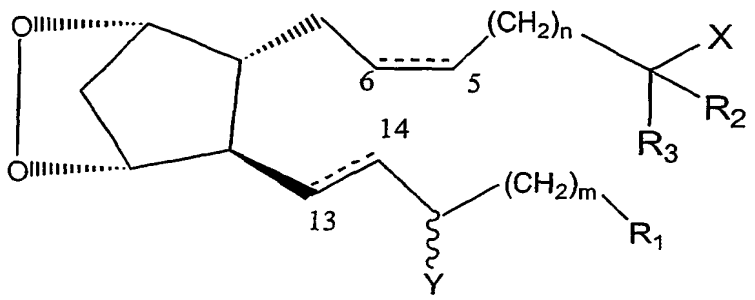
Compounds 54-58 are synthesized from Travoprost acid 9,11-cycloendoperoxide (**Compound 23**), instead of prostaglandin H_2 1-ethanolamide (Compound 17), following General Procedures E, F, G, H and I, respectively, as illustrated in **Reaction Scheme 20** below.



REACTION SCHEME 20

WHAT IS CLAIMED IS:

1. A compound of the formula



wherein the dashed lines represent the presence of a bond, or absence of a bond, wavy lines represent either alpha or beta configuration, solid triangles represent beta configuration and hatched lines represent alpha configuration;

n is an integer having the values of 1 to 6;

m is an integer having the values of 1 to 8;

X is NH_2, $N(R)_2$, NHR, or OR where R is hydrogen, R_4 or a $--(CO)R_4$ group;

Y is =O, =S or OH, OR_5 or $--O(CO)R_5$ groups, said OH, OR_5 or $O(CO)R_5$ groups being attached to the adjacent carbon in alpha or beta configuration;

$\mathbf{R_1}$ is H, CH_3, $\mathbf{R_7}$, $\mathbf{OR_7}$ or $\mathbf{SR_7}$ where $\mathbf{R_7}$ is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to 3 $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, or $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;

R_2 and R_3 together represent =O, =S, or independently are hydrogen or alkyl of 1 to 6 carbon atoms;

R_4 represents $(CH_2)_rOH$, $(CH_2)_rOCOR_9$ or $(CH_2)_rOR_9$ where **r** is an integer having the values 1 to 6, or R_4 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_qR_6$ where q is 0-10 and R_6 is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;

R_5 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_qR_6$, or a pharmaceutically acceptable salt of said compound.

2. A compound in accordance with Claim 1 where n is 3.

3. A compound in accordance with Claim 1 where **m** is an integer having the values 1 to 6.

4. A compound in accordance with Claim 1 where the dotted line between the carbons designated 13 and 14 represents a bond.

5. A compound in accordance with Claim 1 where the dotted line between the carbons designated 13 and 14 represents absence of a bond.

6. A compound in accordance with Claim 1 where the dotted line between the carbons designated 5 and 6 represents a bond.

7. A compound in accordance with Claim 1 where **Y** is =O or OH, or $O(CO)R_5$, where R_5 is alkyl of 1 to 6 carbons.

8. A compound in accordance with Claim 1 where **Y** is OH attached to the adjacent carbon by a bond of alpha orientation.

9. A compound in accordance with Claim 1 where $\mathbf{R_1}$ is methyl, phenyl, O-phenyl, phenyl substituted with 1 to 3 $\mathbf{R_8}$ groups, or O-phenyl substituted with 1 to 3 $\mathbf{R_8}$ groups.

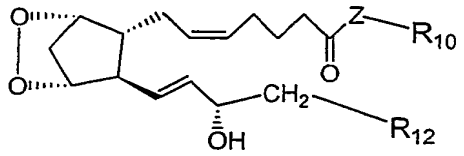
10. A compound in accordance with Claim 1 where R_2 and R_3 jointly form

an oxo (=O) group.

11. A compound in accordance with Claim 9 where OH, OR_4 or NHR_4 or OR_4.

12. A compound in accordance with Claim 10 where $\mathbf{R_4}$ is alkyl of 1 to 6 carbons, or $(CH_2)_rOH$.

13. A compound having the formula



where **Z** is O or NH;

$\mathbf{R_{10}}$ is H, $\mathbf{R_{11}}$ or $(CH_2)_2OH$;

$\mathbf{R_{11}}$ is alkyl of 1 to 3 carbons, and

$\mathbf{R_{12}}$ is selected from the group consisting of *n*-butyl, *n*-hexyl, CH_2-phenyl and O-(3-trifluoromethyl)phenyl.

14. A compound in accordance with Claim 13 where **Z** is O.

15. A compound in accordance with Claim 13 where **Z** is NH.

16. A compound in accordance with Claim 13 where $\mathbf{R_{10}}$ is H.

17. A compound in accordance with Claim 13 where $\mathbf{R_{10}}$ is ethyl.

18. A compound in accordance with Claim 13 where $\mathbf{R_{10}}$ is *iso*-propyl.

19. A compound in accordance with Claim 13 where $\mathbf{R_{10}}$ is CH_2CH_2OH.

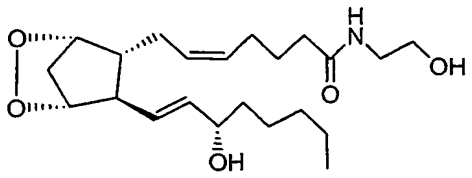
20. A compound in accordance with Claim 13 where $\mathbf{R_{12}}$ is *n*-butyl.

21. A compound in accordance with Claim 13 where $\mathbf{R_{12}}$ is *n*-hexyl.

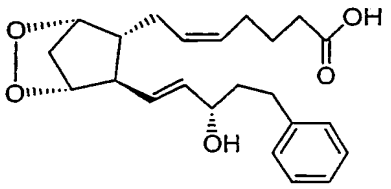
22. A compound in accordance with Claim 13 where $\mathbf{R_{12}}$ is CH_2-phenyl.

23. A compound in accordance with Claim 13 where $\mathbf{R_{12}}$ is O-(3-trifluoromethyl)phenyl.

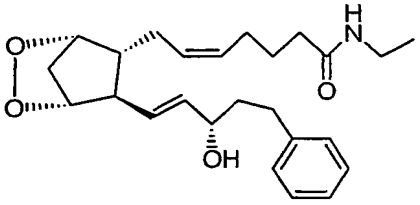
24. A compound in accordance with Claim 13, having the formula



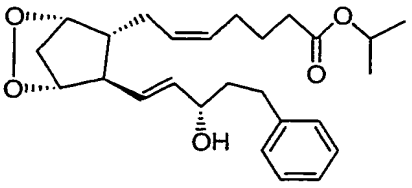
25. A compound in accordance with Claim 13, having the formula



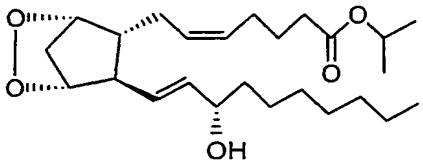
26. A compound in accordance with Claim 13, having the formula



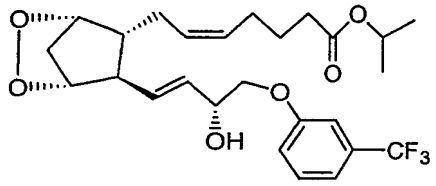
27. A compound in accordance with Claim 13, having the formula



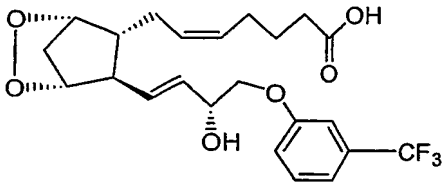
28. A compound in accordance with Claim 13, having the formula



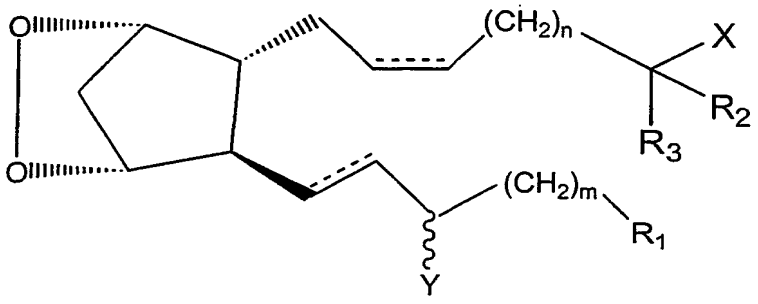
29. A compound in accordance with Claim 13, having the formula



30. A compound in accordance with Claim 13, having the formula



31. A pharmaceutical composition adapted for administration to a mammal, the composition comprising a pharmaceutically acceptable excipient and a compound of the formula



wherein the dashed lines represent the presence of a bond, or absence of a bond, wavy lines represent either alpha or beta configuration, solid triangles represent beta configuration and hatched lines represent alpha configuration;

n is an integer having the values of 1 to 6;

m is an integer having the values of 1 to 8;

X is NH_2, $N(R)_2$, NHR, or OR where R is hydrogen, R_4 or a --$(CO)R_4$ group;

Y is =O, =S or OH, OR_5 or --$O(CO)R_5$ groups, said OH, OR_5 or $O(CO)R_5$ groups being attached to the adjacent carbon in alpha or beta configuration;

$\mathbf{R_1}$ is H, CH_3, $\mathbf{R_7}$, $\mathbf{OR_7}$ or $\mathbf{SR_7}$ where $\mathbf{R_7}$ is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to 3 $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, or $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;

R_2 and R_3 together represent =O, =S, or independently are hydrogen or alkyl of 1 to 6 carbon atoms;

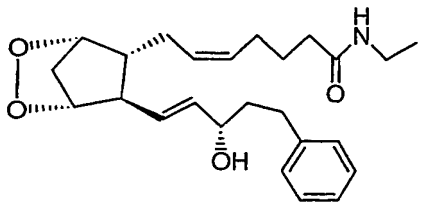
R_4 represents $(CH_2)_rOH$, $(CH_2)_rOCOR_9$ or $(CH_2)_rOR_9$ where **r** is an integer having the values 1 to 6, or R_4 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or --$(CH_2)_qR_6$ where q is 0-10 and R_6 is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;

R_5 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or --$(CH_2)_qR_6$, or a pharmaceutically acceptable salt of said compound.

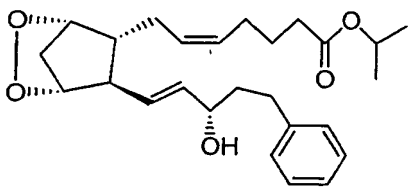
32. A pharmaceutical composition in accordance with Claim 31 which is adapted for administration to a mammal to decrease intraocular pressure in the eye of the mammal.

33. A pharmaceutical composition in accordance with Claim 32 wherein

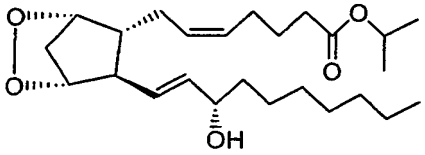
the compound is selected from the group consisting of compounds having the formulas (i) through (vii)



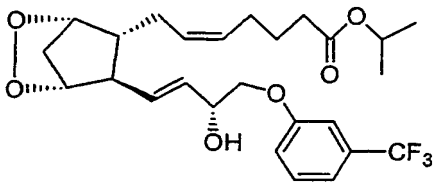
(i)



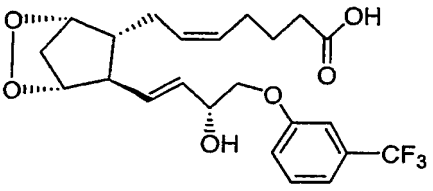
(ii)



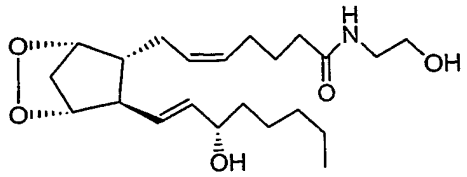
(iii)



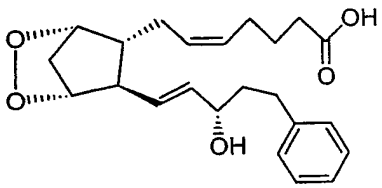
(iv)



(v)



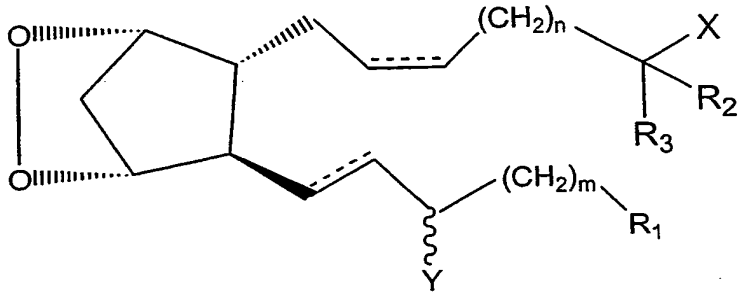
(vi)



(vii)

34. A pharmaceutical composition in accordance with Claim 32 adapted for topical administration to the mammalian eye.

35. A method of administering a pro-drug to a mammal in need of such administration, the pro-drug comprising a compound of the formula



wherein the dashed lines represent the presence of a bond, or absence of a bond, wavy lines represent either alpha or beta configuration, solid triangles represent beta configuration and hatched lines represent alpha configuration;

n is an integer having the values of 1 to 6;

m is an integer having the values of 1 to 8;

X is NH_2, $N(R)_2$, NHR, or OR where R is hydrogen, R_4 or a $--(CO)R_4$ group;

Y is =O, =S or OH, OR_5 or $--O(CO)R_5$ groups, said OH, OR_5 or $O(CO)R_5$ groups being attached to the adjacent carbon in alpha or beta configuration;

$\mathbf{R_1}$ is H, CH_3, $\mathbf{R_7}$, $\mathbf{OR_7}$ or $\mathbf{SR_7}$ where $\mathbf{R_7}$ is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to 3 $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, or $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;

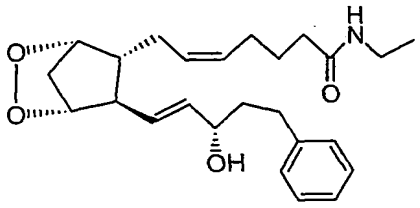
R_2 and R_3 together represent =O, =S, or independently are hydrogen or alkyl of 1 to 6 carbon atoms;

R_4 represents $(CH_2)_rOH$, $(CH_2)_rOCOR_9$ or $(CH_2)_rOR_9$ where **r** is an integer having the values 1 to 6, or R_4 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_qR_6$ where q is 0-10 and R_6 is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;

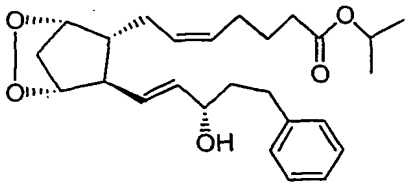
R_5 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_qR_6$, or a pharmaceutically acceptable salt of said compound.

36. A method in accordance with Claim 35 wherein the pro-drug is administered to decrease intraocular pressure in the eye of the mammal.

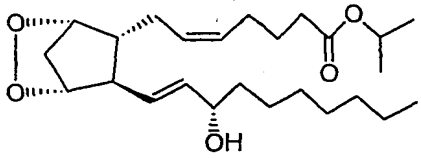
37. A method in accordance with Claim 36 wherein the compound is selected from the group consisting of compounds having the formulas (i) through (vii)



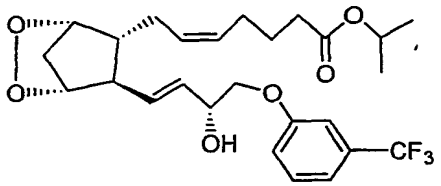
(i)



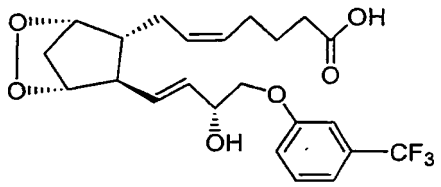
(ii)



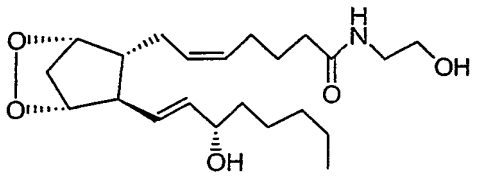
(iii)



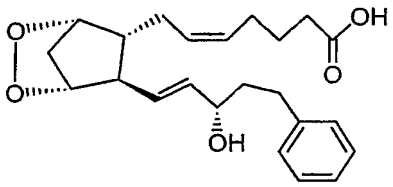
(iv)



(v)



(vi)



(vii)

38. A method in accordance with Claim 37 wherein the pro-drug is administered topically to decrease intraocular pressure in the eye of the mammal.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/24305

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C07D317/06 A61K31/357 A61P27/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C07D A61K A61P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, CHEM ABS Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RAZ, AMIRAM ET AL: "Endoperoxides and thromboxanes. Structural determinants for platelet aggregation and vasoconstriction" BIOCHIMICA ET BIOPHYSICA ACTA (1977), 488(2), 305-11 , XP008025412 figure 3 ---	1,31
X	WO 02 12445 A (UNIV VANDERBILT) 14 February 2002 (2002-02-14) fig. 7 and 8, PGH2-EA ---	1
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 December 2003	08/01/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Alfaro Faus, I

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 03/24305

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

Although claims 35-38 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compounds.

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/24305

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	GORMAN R R ET AL: "PROSTAGLANDIS H1 AND H2. CONVENIENT BIOCHEMICAL SYNTHESIS AND ISOLATION. FURTHER BIOLOGICAL AND SPECTROSCOPIC CHARACTERIZATION" PROSTAGLANDINS, BUTTERWORTH, STONEHAM, MA, US, vol. 13, no. 6, June 1977 (1977-06), pages 1043-1053, XP001160973 ISSN: 0090-6980 page 1044 -page 1046; table 1 ---	1
X	GRAFF, G. ET AL: "Identification of 15-keto-9,11-peroxidoprosta-5,13-dienoic acid as a hematin-catalyzed decomposition product of 15-hydroperoxy-9,11-peroxidoprosta-5,13-dienoic acid" LIPIDS (1979), 14(4), 334-42 , XP008025451 figure 7 ---	1
X	DICZFALUSY, ULF ET AL: "Enzymic conversion of C21 endoperoxides to thromboxanes and hydroxy acids" BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS (1980), 94(4), 1417-23 , XP008025450 figure 4 ---	1
X	LEDUC, LOUISE E. ET AL: "Analogs of arachidonic acid used to evaluate structural determinants of prostaglandin receptor and enzyme specificities" MOLECULAR PHARMACOLOGY (1981), 19(2), 242-7 , XP008025459 table 2 -----	1

INTERNATIONAL SEARCH REPORT

ın on patent family members

International Application No
PCT/US 03/24305

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO 0212445 A	14-02-2002	AU	8474701 A	18-02-2002
		AU	8475301 A	18-02-2002
		CA	2422306 A1	14-02-2002
		CA	2422803 A1	14-02-2002
		EP	1307585 A1	07-05-2003
		EP	1307538 A1	07-05-2003
		WO	0212549 A1	14-02-2002
		WO	0212445 A1	14-02-2002
		US	2002064804 A1	30-05-2002
		US	2002106707 A1	08-08-2002

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 February 2004 (12.02.2004)

PCT

(10) International Publication Number
WO 2004/013119 A1

(51) International Patent Classification[7]: C07D 317/06, A61K 31/357, A61P 27/00

(21) International Application Number: PCT/US2003/024305

(22) International Filing Date: 4 August 2003 (04.08.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/212,437 5 August 2002 (05.08.2002) US

(71) Applicant: ALLERGAN, INC. [US/US]; 2525 Dupont Drive, Irvine, CA 92612 (US).

(72) Inventors: LING, Kah-Hiing, John; 82 Lessay, Newport Coast, CA 92657 (US). YANG, Wu; 1 Corte Trovata, Irvine, CA 92606 (US). NI, Jinsong; 9 Coca, Foothill Ranch, CA 92610 (US). YUAN, Haiqing; 28 Del Trevi, Irvine, CA 92606 (US). TANG-LIU, Diane, D., S.; 2615 Blackthorn Street, Newport Beach, CA 92660 (US).

(74) Agents: FISHER, Carlos, A. et al.; c/o Allergan, Inc., 2525 Dupont Drive, Irvine, CA 92612 (US).

(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

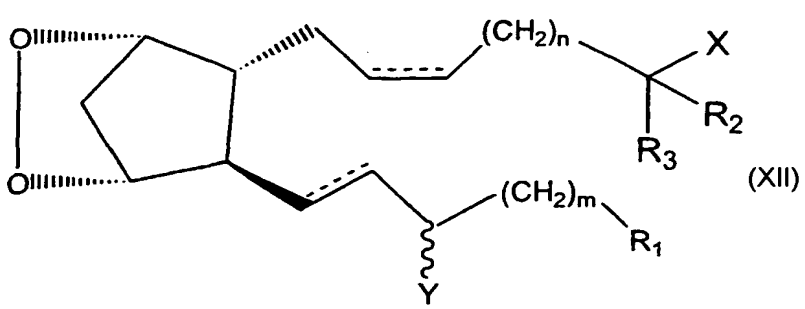
(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report
— with amended claims and statement

Date of publication of the amended claims and statement:
6 May 2004

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: THE 9, 11-CYCLOENDOPEROXIDE PRO-DRUGS OF PROSTAGLANDIN ANALOGUES FOR TREATMENT OF OCULAR HYPERTENSION AND GLAUCOMA



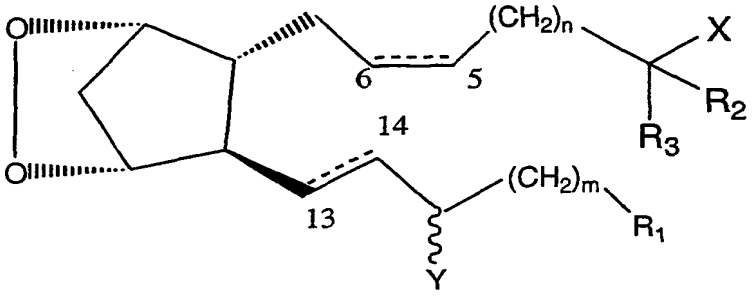
(XII)

(57) Abstract: 9,11-Cycloendoperoxide derivatives of biologically active prostaglandin analogs, and particularly of the ocular hypotensive drugs Bimatoprost, Latanaprost, Unoprostone, Travoprost and prostaglandin H_2 1-ethanolamide or of structurally closely related analogs, are pro-drugs which hydrolyze under physiological conditions to provide prostaglandin analogues that are capable of providing sustained ocular and other in vivo concentrations of the respective drugs. The compounds of the invention have the formula shown below where the variables have the meaning defined in the specification.

WO 2004/013119 A1

AMENDED CLAIMS
[Received by the International Bureau on 01 March 2004 (01.03.04): original claims 1-38 replaced by amended claims bearing the same numbers (12 pages)]

1. (currently amended) A compound of the formula



wherein the dashed lines represent the presence of a bond, or absence of a bond, wavy lines represent either alpha or beta configuration, solid triangles represent beta configuration and hatched lines represent alpha configuration;

n is an integer having the values of 1 to 6;

m is an integer having the values of 1 to 8;

X is NH_2, $N(R)_2$, NHR, or OR where R is hydrogen, R_4 or a --$(CO)R_4$ group;

Y is =S or OH, OR_5 or --$O(CO)R_5$ groups, said OH, OR_5 or $O(CO)R_5$ groups being attached to the adjacent carbon in alpha or beta configuration;

$\mathbf{R_1}$ is H, CH_3, $\mathbf{R_7}$, $\mathbf{OR_7}$ or $\mathbf{SR_7}$ where $\mathbf{R_7}$ is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to 3 $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, or $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;

$\mathbf{R_2}$ and $\mathbf{R_3}$ together represent =O, =S, or independently are hydrogen or alkyl of 1 to 6 carbon atoms, with the proviso that when **X** is **OR** then $\mathbf{R_1}$ is not H nor methyl;

$\mathbf{R_4}$ represents $(CH_2)_rOH$, $(CH_2)_rOCOR_9$ or $(CH_2)_rOR_9$ where **r** is an integer having the values 1 to 6, or R_4 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_qR_6$ where q is 0-10 and R_6 is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to $\mathbf{R_8}$ groups where $\mathbf{R_8}$ is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3 with the further proviso that when **X** is NH**R**, **m** is 4 and $\mathbf{R_1}$ is methyl then $\mathbf{R_4}$ is not $(CH_2)_2OH$;

$\mathbf{R_5}$ represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_q\mathbf{R_6}$, or a pharmaceutically acceptable salt of said compound.

2. A compound in accordance with Claim 1 where n is 3.

3. A compound in accordance with Claim 1 where m is an integer having the values 1 to 6.

4. A compound in accordance with Claim 1 where the dotted line between the carbons designated 13 and 14 represents a bond.

5. A compound in accordance with Claim 1 where the dotted line between the carbons designated 13 and 14 represents absence of a bond.

6. A compound in accordance with Claim 1 where the dotted line between the carbons designated 5 and 6 represents a bond.

7. A compound in accordance with Claim 1 where Y is =O or OH, or $O(CO)R_5$, where R_5 is alkyl of 1 to 6 carbons.

8. A compound in accordance with Claim 1 where Y is OH attached to the adjacent carbon by a bond of alpha orientation.

9. A compound in accordance with Claim 1 where R_1 is methyl, phenyl, O-

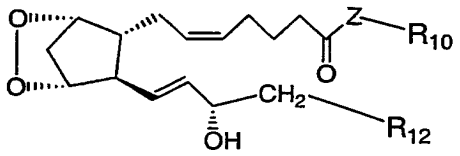
phenyl, phenyl substituted with 1 to 3 R_8 groups, or O-phenyl substituted with 1 to 3 R_8 groups.

10. A compound in accordance with Claim 1 where R_2 and R_3 jointly form an oxo (=O) group.

11. (currently amended) A compound in accordance with Claim 9 where X is OH, OR_4 or NHR_4.

12. A compound in accordance with Claim 10 where R_4 is alkyl of 1 to 6 carbons, or $(CH_2)_rOH$.

13. (currently amended) A compound having the formula



where Z is O or NH;

R_{10} is H, R_{11} or $(CH_2)_2OH$;

R_{11} is alkyl of 1 to 3 carbons, and

R_{12} is selected from the group consisting of *n*-butyl, *n*-hexyl, CH_2-phenyl and O-(3-trifluoromethyl)phenyl with the proviso that when Z is O and R_{12} is *n*-butyl then R_{10} is not H nor R_{11}, with the further proviso that when Z is NH and R_{12} is *n*-butyl then R_{10} is not $(CH_2)_2OH$.

14. A compound in accordance with Claim 13 where Z is O.

15. A compound in accordance with Claim 13 where Z is NH.

16. A compound in accordance with Claim 13 where R_{10} is H.

17. A compound in accordance with Claim 13 where R_{10} is ethyl.

18. A compound in accordance with Claim 13 where R_{10} is *iso*-propyl.

19. A compound in accordance with Claim 13 where R_{10} is CH_2CH_2OH.

20. A compound in accordance with Claim 13 where R_{12} is *n*-butyl.

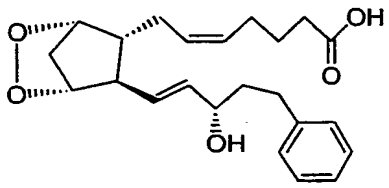
21. A compound in accordance with Claim 13 where R_{12} is *n*-hexyl.

22. A compound in accordance with Claim 13 where R_{12} is CH_2-phenyl.

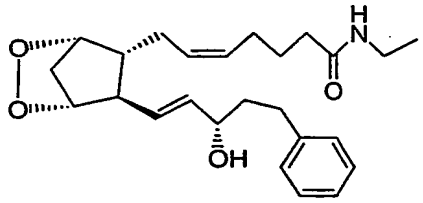
23. A compound in accordance with Claim 13 where R_{12} is O-(3-trifluoromethyl)phenyl.

24. (canceled)

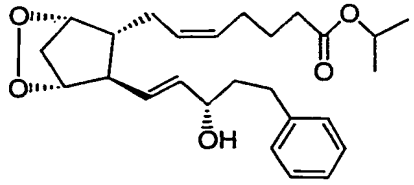
25. A compound in accordance with Claim 13, having the formula



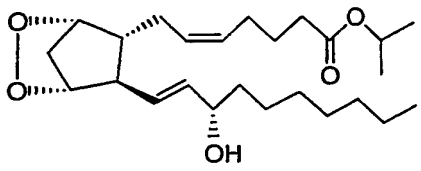
26. A compound in accordance with Claim 13, having the formula



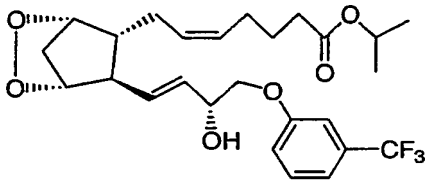
27. A compound in accordance with Claim 13, having the formula



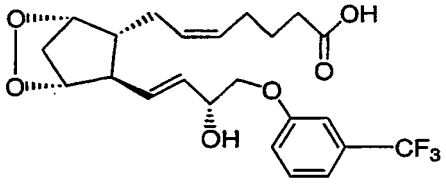
28. A compound in accordance with Claim 13, having the formula



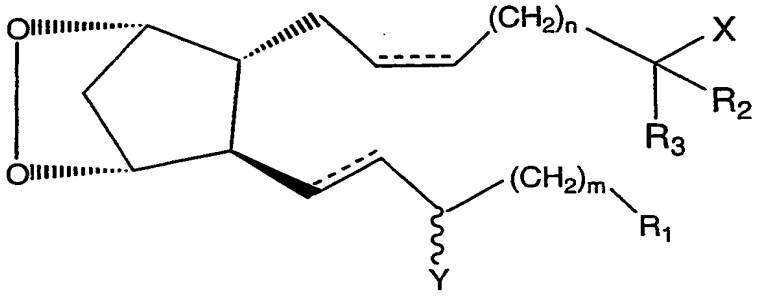
29. A compound in accordance with Claim 13, having the formula



30. A compound in accordance with Claim 13, having the formula



31. A pharmaceutical composition adapted for administration to a mammal, the composition comprising a pharmaceutically acceptable excipient and a compound of the formula

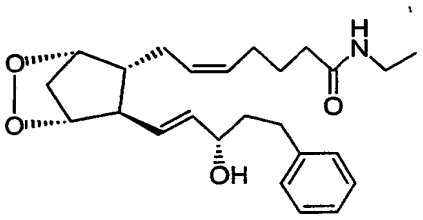


wherein the dashed lines represent the presence of a bond, or absence of a bond, wavy lines represent either alpha or beta configuration, solid triangles represent beta configuration and hatched lines represent alpha configuration;
n is an integer having the values of 1 to 6;
m is an integer having the values of 1 to 8;
X is NH_2, $N(R)_2$, NHR, or OR where R is hydrogen, R_4 or a --$(CO)R_4$ group;
Y is =O, =S or OH, OR_5 or --$O(CO)R_5$ groups, said OH, OR_5 or $O(CO)R_5$ groups being attached to the adjacent carbon in alpha or beta configuration;
R_1 is H, CH_3, R_7, OR_7 or SR_7 where R_7 is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to 3 R_8 groups where R_8 is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, or $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;
R_2 and R_3 together represent =O, =S, or independently are hydrogen or alkyl of 1 to 6 carbon atoms;

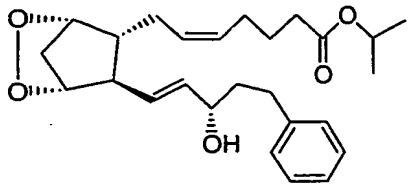
R_4 represents $(CH_2)_rOH$, $(CH_2)_rOCOR_9$ or $(CH_2)_rOR_9$ where r is an integer having the values 1 to 6, or R_4 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_qR_6$ where q is 0-10 and R_6 is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to R_8 groups where R_8 is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;
R_5 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or $--(CH_2)_qR_6$, or a pharmaceutically acceptable salt of said compound.

32. A pharmaceutical composition in accordance with Claim 31 which is adapted for administration to a mammal to decrease intraocular pressure in the eye of the mammal.

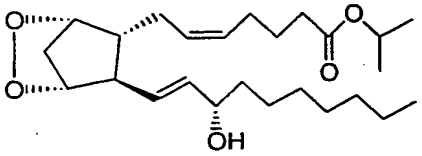
33. A pharmaceutical composition in accordance with Claim 32 wherein the compound is selected from the group consisting of compounds having the formulas (i) through (vii)



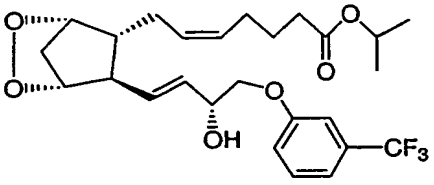
(i)



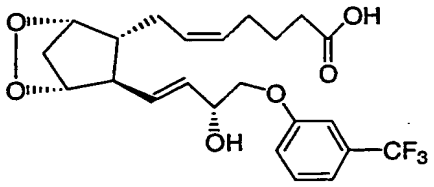
(ii)



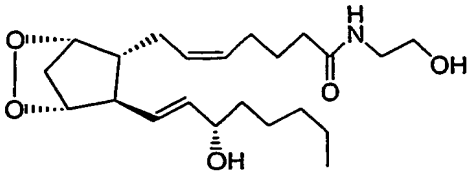
(iii)



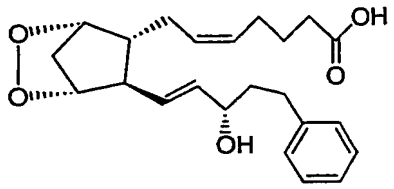
(iv)



(v)



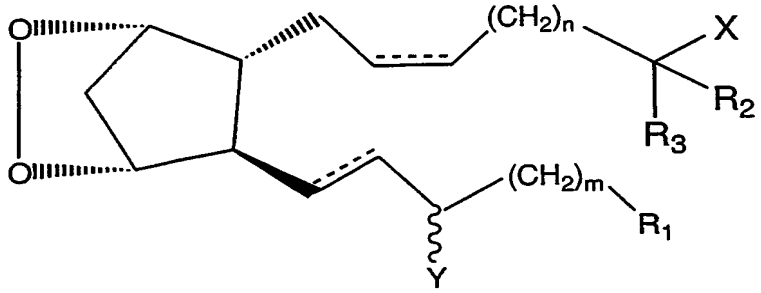
(vi)



(vii)

34. A pharmaceutical composition in accordance with Claim 32 adapted for topical administration to the mammalian eye.

35. A method of administering a pro-drug to a mammal in need of such administration, the pro-drug comprising a compound of the formula



wherein the dashed lines represent the presence of a bond, or absence of a bond, wavy lines represent either alpha or beta configuration, solid triangles represent beta configuration and hatched lines represent alpha configuration;

n is an integer having the values of 1 to 6;

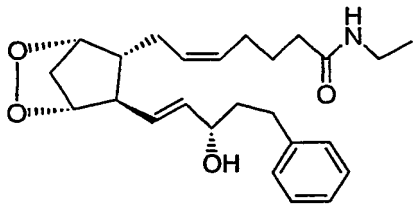
m is an integer having the values of 1 to 8;

X is NH_2, $N(R)_2$, NHR, or OR where R is hydrogen, R_4 or a --$(CO)R_4$ group;

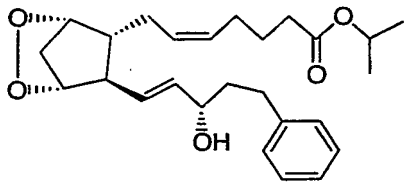
Y is =O, =S or OH, OR_5 or --$O(CO)R_5$ groups, said OH, OR_5 or $O(CO)R_5$ groups being attached to the adjacent carbon in alpha or beta configuration;
R_1 is H, CH_3, R_7, OR_7 or SR_7 where R_7 is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to 3 R_8 groups where R_8 is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, or $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;
R_2 and R_3 together represent =O, =S, or independently are hydrogen or alkyl of 1 to 6 carbon atoms;
R_4 represents $(CH_2)_rOH$, $(CH_2)_rOCOR_9$ or $(CH_2)_rOR_9$ where r is an integer having the values 1 to 6, or R_4 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or --$(CH_2)_qR_6$ where q is 0-10 and R_6 is an aliphatic, aromatic or heteroaromatic ring, said heteroaromatic ring having 1 to 3 heteroatoms selected from O, S, and N, said aliphatic, aromatic or heteroaromatic ring being optionally substituted with 1 to R_8 groups where R_8 is F, Cl, Br, I, NO_2, C_{1-6} alkyl, C_{1-6} fluoro substituted alkyl, COOH, $COOR_9$ where R_9 is alkyl of 1 to 6 carbons or CH_2OCH_3;
R_5 represents saturated or unsaturated acyclic hydrocarbons having from 1 to 20 carbon atoms, or --$(CH_2)_qR_6$, or a pharmaceutically acceptable salt of said compound.

36. A method in accordance with Claim 35 wherein the pro-drug is administered to decrease intraocular pressure in the eye of the mammal.

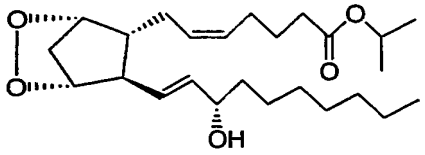
37. A method in accordance with Claim 36 wherein the compound is selected from the group consisting of compounds having the formulas (i) through (vii)



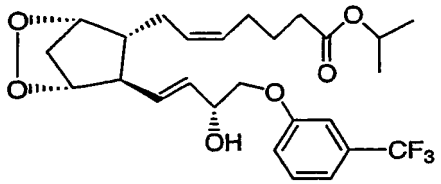
(i)



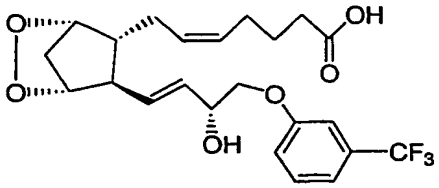
(ii)



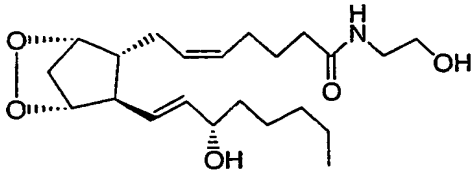
(iii)



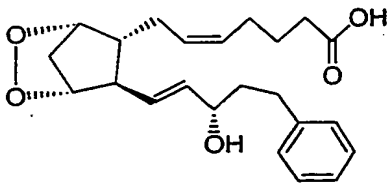
(iv)



(v)



(vi)



(vii)

38. A method in accordance with Claim 37 wherein the pro-drug is administered topically to decrease intraocular pressure in the eye of the mammal.

PATENT COOPERATION TREATY

International Application No. PCT/US 03/ 24305
International Filing Date: 04/ 08/ 2003
Applicant: ALLERGAN, INC.
Priority: 05/ 08/ 2002
Based on U.S. Serial No. 10/212,437
Attorney's Docket: 17497 (HL)

International Bureau of WIPO
34 chemin des Colombettes
1211 Geneva 20, Switzerland

STATEMENT UNDER ARTICLE 19(1) (Rule 46.4)

Claims were amended (as applicable) and Claim 24 was canceled to clearly and unequivocally avoid subject matter that came to applicant's attention during U.S. prosecution, namely the references *Bylund et al.* (J. Biol. Chem., 275 (29) pp 21844 – 21849) and/or the *Porter et al.* (J. Org. Chem. 48 (10) 1978 pp 2088 – 2090), and/or subject matter that applicant became aware of as a result of the International Search.

The foregoing was accomplished by adding provisos in Claims 1 and 13, and by deleting "=O" from the definition of the variable Y in Claim 1. Claim 11 was amended to correct an inadvertent error in the original claim language. The correction is supported by the specification where it is stated that "the variable X is preferably OH, OR_4 or NHR_4".

Respectfully Submitted

Date: February 19, 2004

Carlos Fisher, Esq.

ALLERGAN, INC.
2525 Dupont Drive
Irvine, CA 92612